SOCIOECONOMIC AND SPATIAL IMPACTS OF RAIL TRANSIT STATIONS ON THE SURROUNDING

AREAS IN DALLAS-FORT WORTH REGION: CHANGES IN HOUSING

VALUES, RACIAL MAKE-UP, AND POPULATION DENSITY

by

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Abstract

SOCIOECONOMIC AND SPATIAL IMPACTS OF RAIL TRANSIT STATIONS ON THE SURROUNDING

AREAS IN DALLAS-FORT WORTH METROPOLITAN AREA: CHANGES IN HOUSING

VALUES, RACIAL MAKE-UP, AND POPULATION DENSITY

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Dependency on the automobile in the United States has been associated with many urban problems, such as urban sprawl, traffic congestion, air pollution, etc. As the use of automobiles increases, negative externalities also increase. As a result, many American cities have seen a rebound of public transportation systems—many of which have built modern rail transit systems to mitigate the negative impacts of higher dependency on automobiles, to improve mobility and accessibility for commuters, to offer alternative to drivers, to shape development patterns, and to increase economic growth. This rebound of rail transit systems has caused apparent shifts in economic, social, and spatial aspects of neighborhoods located in proximity to rail stations, but negative impacts may still also occur.

This study investigates the changes in housing value, racial make-up, and population density between 2000 and 2014 in 454 block groups within a one-mile buffer around rail stations located in the Dallas-Fort Worth metropolitan area, specifically in the four counties served by the passenger rail transit systems (Collin, Dallas, Denton, and Tarrant counties). This study begins with a comparison of economic, social, and spatial changes between 2000 and 2014 in the block groups within a one-mile radius around rail stations. It also compares the changes in block groups within a one-mile radius to the remainder of the block groups within the four counties served by rail transit systems (2610 block groups). This is followed by running regression models with the data on the block groups located within the one-mile buffer around rail stations to understand the relationships between the selected independent variables

and the dependent variables. Data was collected from many sources and analyzed by different techniques, such as ArcGIS and SPSS, to answer the research questions in order to suggest some solutions for increasing housing value, population density, and attracting a more diverse population to the study area.

Several of the results are surprising. Within the block groups around rail stations, changes in median housing value and the number of white residents are greater than the rest of block groups within the four counties. However, changes in total population, population density, the number of black, Hispanic, college educated, and civil employed residents, plus the number of jobs per block group, are greater within the block groups located beyond the one-mile buffer, especially toward outlying areas. The basic results of the regression models of the data related to block groups located within a one-mile radius around rail stations show that, during the study period, closer block groups to rail stations experienced an increase in the number of white residents, a decrease in housing value, and a decrease in population density, compared to block groups located farther away from stations. These findings are a useful addition to the existing literature and represent a contribution to the field of urban planning. In addition, urban planners and policymakers should adopt some policy implications for furthering the success of rail transit systems in the DFW area, increasing the transit usage, and sustaining station area development. Policymakers should promote transit-oriented development (TOD) with good urban design, improve rail transit coverage and quality, and alleviate negative externalities associated with rail transit stations.

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Chapter 1

Introduction

1.1 Background

The growing dependency on the private automobile in the United States has been associated with some urban problems such as urban sprawl, air pollution, traffic congestion, and car accidents (Cervero & Bosselmann, 1994; Ewing et al., 2008). This means that as the use of the private motor vehicle increases, negative externalities also increase. For example, as shown in Figure 1-1, the number of U.S. workers commuting to work by private vehicles increased from 64% in 1960, to its peak at 88% in 2000, but the number has since declined slightly to 85.8% in 2013. Also, driving alone to work increased sharply during the 1980s, and has continued to grow up until 2013 (although more slowly). Moreover, carpooling has decreased since the 1980s, and only continues to decline in the present (McKenzie, 2015). Therefore, a large number of American cities have seen a rebound of public transportation systems and most of them have built modern rail transit systems not only to mitigate the negative impacts of higher dependency on private automobiles, but also to improve the mobility and accessibility for commuters, offer alternative to drivers, shape development patterns, increase employment opportunities, and increase economic growth (Guerra, 2014; Levy, 2010; Pacheco-Raguz, 2010; Weisbrod & Reno, 2009).
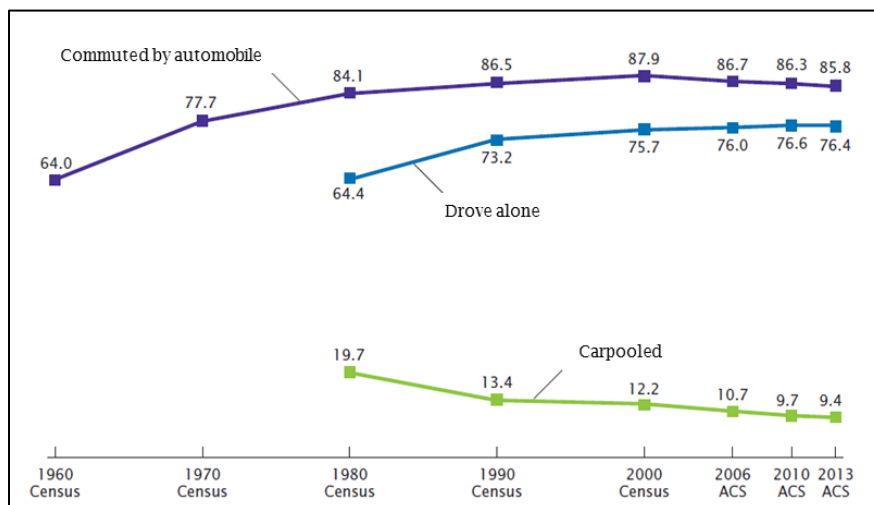
Figure 1-1 Workers commuting by automobile: 1960 to 2013

The return to rail transit systems has caused apparent shifts in economic, social, and spatial aspects of neighborhoods in close proximity to rail stations (Baum-Snow & Kahn, 2000; Dawkins & Moeckel, 2014; Lin, 2002; Pacheco-Raguz, 2010). These shifts differ between cities and even between stations within the same line and these differences could be due to some factors such as land use regulations, travel behaviors, distance to other influences, and some social and economic factors (Guerra, 2014). Rail transit systems have wide-ranging impacts on development patterns and quality of life (Huang, 1996); further, they may enhance economic growth (Cervero et al., 1995; Huang, 1996; Litman, 2015) and lead to agglomeration economies in some industries (Glaeser, 2011). These industries contribute to the increase in population and employment densities in the area surrounding rail stations (Glaeser, 2011). In addition, one of the major effects generated by rail transit systems is the positive changes in property value and rent (Clower & Weinstein, 2002). It may also attract higher-income transit commuters to locate near rail stations due to better accessibility generated by rail transit systems (Beaton, 2006; Dill, 2008; Gossen, 2005; Lin, 2002).

However, rail transit stations might affect the neighborhoods surrounding rail transit stations negatively and decrease property value and rent due to negative externalities associated with rail transit systems, such as higher traffic congestion, crime rates, noise, and pollution (Chen, Rufolo, & Dueker, 1998; Kim & Zhang, 2005; Mohammad et al., 2013; Wardrip, 2011). Rail stations sometimes act as poverty magnets as Baum-Snow and Kahn (2005), and Glaeser et al. (2008) claimed, since low-income people are transit-dependent riders. Furthermore, rail transit stations in some cities increased crime rates in parking lots and neighborhoods surrounding rail stations (Bowes & Ihlanfeldt, 2001). In addition, a zero or weak impact from rail transit systems is also reported in several studies in regard to property value, rent, population densities, or changes in socioeconomic characteristics of residents (Gatzlaff & Smith, 1993; Kim & Zhang, 2005).

This research examines if the effects of rail transit stations in the Dallas-Fort Worth (DFW) metropolitan area on nearby neighborhoods are positive, negative, or have no impact at all. The major impacts taken into account are related to changes in some economic aspects, socioeconomic attributes of residents, and development patterns in some chosen geographic census units. These indicators can

be analyzed in order to explore the impacts of proximity to rail transit stations on identified geographic census units within a certain distance from the rail stations.

1.2 Problem Statement and the Significance of Research

As mentioned in the introduction, rail transit systems can affect property value, socioeconomic characteristics of the residents, and spatial patterns of neighborhoods surrounding rail stations either positively or negatively. However, a review of the professional literature could not find any significant impact or claim that either the positive or converse impacts of rail transit are less understood (Pacheco-Raguz, 2010). Thus, planners believe that as the interest in building rail transit system increases, the need to understand the general impacts increases and becomes more essential. The impacts of rail stations on adjacent areas also have to be taken into consideration. In other words, researchers should examine the changes in areas surrounding rail stations and compare the impacts over the last few years to the impacts from a couple of years ago to understand and measure impact trends.

This research attempts to study the effects of the rail transit stations on the surrounding areas in the DFW metropolitan area and looks for some economic, social, and spatial changes over a long period of time to find and examine the extent and the type of impacts that result from proximity to rail transit stations. Therefore, this study is important for many reasons. First, this study looks at various aspects: the economic, social, and spatial impacts of rail transit systems in the DFW area. However, most of the existing studies focus only on one type of impact, such as the impact on residential value or the effect on development patterns. Second, most of the existing studies examine the area within one-quarter to one-half a mile buffer around rail stations. However, this study will analyze wider proximity measures since most of the rail stations in DFW area have park-and-ride facilities, which may widen the impact of the rail station and attract more riders from neighborhoods located more than half a mile from stations. Also, the smaller radius may not capture all impacts of rail transit since some effects may extend farther out, or there will be no or negative impacts within the closest areas to stations, and the actual impacts start to appear beyond this distance. Third, a significant number of existing literature uses a large geographic census unit (e.g. ZIP codes and census tracts) to predict the impact of rail stations, while several studies use a parcel as the unit of measure. However, this study will use a block group as a unit to measure the

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changes and impacts of rail stations on nearby areas since the results of smaller geographic census units are more accurate than the larger ones.

Fourth, this study uses the most accurate technique to determine the inclusion and exclusion of the block groups being studied. Much of the prior work either did not mention the techniques being used or used least accurate techniques. The analysis methodology used in any study can affect the accuracy of the results; so, in this study, a comparison between socioeconomic and spatial changes over a long period of time and multivariate regression models will be used. This study covers changes between 2000 and 2014, which can be considered a long period of time where the evaluation always has strong impact, since most short-term impact is near zero. However, very few existing studies use changes between long periods of time; most of them use one single year. After comparing the changes between 2000 and 2014, this study will use multivariate regression models to estimate the rail transit stations impacts on socioeconomic and spatial aspects of neighborhoods surrounding rail stations. Regression models are one of the most accurate methods to predict the changes in the dependent variables and to determine other factors that may contribute to an effect on the dependent variables. Moreover, a good number of independent variables from social and economic theories and literature review will be included in the regression models to answer the research questions and give more explanation of the dependent variable—since many existing studies included only a few independent variables. Additionally, the mixed results of previous studies that examine the impact of rail transit systems show the importance of carrying out this research.

Above all, the strong rational reason for doing this study in this specific metropolitan area is that there are only a few studies that have been done about rail transit in the DFW area, even though it has the longest transit rail network in the U.S. (Crossley, 2010; McMillan, 2014), and it was funded by many sources due its very high cost. Those studies only covered Dallas Area Rapid Transit (DART), which serves the city of Dallas and 12 member cities. No published study covered all rail transit systems in the DFW metropolitan area. However, there is a good deal of research about the impacts of transit rail in other major U.S. cities (Gatzlaff & Smith, 1993). For example, since the early 1970s, many studies have extensively examined the impact of the San Francisco Bay Area Rapid Transit (BART) system, which is

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considered the first large-scale urban rail system built in the county (e.g. Baldassare et al., 1979; Cervero, & Duncan, 2002a; Cervero, & Landis, 1997; Cervero, & Wu, 1998; Davis, 1970; Dornbusch, 1975; Landis et al., 1994; Landis, & Loutzenheiser, 1995; Lee, 1973). Other studies have widely examined the impacts of the Metropolitan Atlanta Rapid Transit Authority (MARTA) system (e.g. Bollinger & Ihlanfeldt, 1997; Bowes, & Ihlanfeldt, 2001; Cervero, 1994; Nelson, 1992, 1999; Nelson & McCleskey, 1990). Many studies have investigated the effects of MAX light rail in Portland on the surrounding areas (e.g. Al-Mosaind et al., 1993; Chen et al., 1998; Dueker & Bianco, 1999; Knaap, Ding, & Hopkins, 2001; Lewis-Workman & Brod, 1997; Song & Knaap, 2003). Furthermore, plenty of articles have been written about the different impacts of Washington, D.C. Metro system (e.g. Benjamin, & Sirmans, 1996; Cervero, 1994; Damm et al., 1980; Donnelly, 1982; Grass, 1992).

Covering larger geographic area by rail transit system may show better results than what other scholars have found in smaller study areas. However, cities served by rail transit in the DFW metropolitan area have a low population density, and they are auto-oriented cities. Therefore, the investment of rail transit in these cities may not improve the accessibility of a location enough to attract more residents and businesses to locate in proximity to rail stations, which in turn makes the results of this study different from anywhere else.

As a result, this study is an addition to the literature related to urban planning in general. Specifically, it contributes valuable information to the literature related to the impact of rail transit stations on the changes to the housing market, residents' demographics, and population density of neighborhoods surrounding rail stations—especially if those neighborhoods are located in a metropolitan area that is characterized by auto-oriented and low-density developments. If the results of this study show that the rail transit stations have effects on the housing market, socioeconomic attribute of residents, and population density, and those factors are statistically significant and have strong relationships, then this study would have major planning and policy implications on affordability of housing, equitable mixed use developments, and social equity. Moreover, these planning and policy implications could be applicable to other large metropolitan area. However, if the study shows some unexpected results related to the impacts of proximity to rail stations on changes in housing value and socioeconomic attributes of

residents, urban planners and decision-makers should adopt some local and government policies motivating more sustainable development around rail stations to improve transit accessibility.

1.3 Research Purpose and Questions

This dissertation seeks to shed light on the significant impacts of rail transit stations in the Dallas-Fort Worth metropolitan area on the nearby neighborhoods. In particular, this study tries to find and understand the effects of the investment in rail transit in the DFW area on changes in some economic, social, and spatial factors between 2000 and 2014 in the area surrounding rail stations. Also, this study tries to compare the changes in the areas next to rail stations in the period between 2000 and 2014, and compare them to the changes in the four counties served by rail transit systems (Collin, Dallas, Denton, and Tarrant).

As was discussed briefly in the introductory section, rail transit stations affect the surrounding areas. These effects can be categorized in three sets of economic, social, and spatial impacts and this research would like to study the effects of rail stations in the DFW area on these three categories. However, as the literature review in the next section shows, there are several variables in each one of these categories. As an example, we can identify residential property value and rent (e.g. single-family housing, multi-family housing, and condominiums), commercial, retail, office, and industrial properties values, as just a few of the important variables related to the economic factors. Therefore, considering the limitations that a dissertation has, this research will limit itself to select one major variable for each of the economic, social, and spatial aspects whose effects are being studied.

After a thorough review of the relevant literature, the impact of rail transit stations on housing value is selected for the economic category. Many existing studies have examined the impact of rail transit stations on housing value of neighborhoods surrounding rail stations and found that housing value is greater near stations than the value of housing units located farther away from stations (e.g. Al-Mosaind et al., 1993; Armstrong, 1994; Chen et al., 1998; Duncan, 2008; Grass, 1992; Hess & Almeida, 2006; Mathur & Ferrell, 2013; Voith, 1993; Weinstein & Clower, 1999). Housing value was chosen because this type of land use is the dominant one within the block groups located next to rail stations; it

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represents around 50% of land uses. Also, the data for this type of use is available, while the data for the value of other land uses is more difficult to find.

Regarding the social aspects, the literature has typically emphasized racial and ethnic patterns. Due to the limitations of this research, the effects of rail stations on changes in the population of white residents was selected as the dependent variable for the social category rather than blacks or Hispanics. Some of the literature has examined the impact of rail transit stations on the race of residents and the results are mixed (Baum-Snow & Kahn, 2000; Farrow, 2001; McKenzie, 2013; Pollack et al., 2010; Renne, 2005). However, no study have been found using white residents as dependent variable, so this study tries to fill the knowledge gap about changes in white residents in neighborhoods located in proximity to rail stations. Furthermore, the justification of testing the impact of rail transit stations on the changes in white population is that the DFW area is still one of the top destinations for people moving from other states, especially white residents, so this study investigates whether the rail stations attract more white residents than other locations or not..

Regarding the spatial patterns, the literature has mainly focused on changes in land uses and population density. However, this research is limited to examine the impact of rail transit stations on population density for block groups next to rail stations. Most of the existing studies have concluded that neighborhoods near rail stations have a higher population density than the neighborhoods located farther away from rail stations (Arrington & Cervero, 2008; Beaton, 2006; Bernick, 1993; Bernick & Cervero, 1994a; Knight & Trygg, 1977; Shen, 2013). The main reason for selecting this factor is that cities within the DFW area have low population density, so this research tries to see if the neighborhoods next to stations have higher population density or not.

This research will use three approaches to analyze the data. First, a comparison of changes in economic, social, and spatial factors within block groups located in one mile of the rail station areas, which can be called the "study area", between 2000 and 2014 will be introduced. Next, a comparison of the study area to the rest of block groups located within the four counties served by rail transit system in 2000 and 2014 will be presented. Finally, these will be followed by the application of multiple regression

models that will try to reject the null hypotheses and answer to the research questions. Thus, the research questions posed are:

1. Does proximity to rail stations in the DFW area affect median housing value for the period between 2000 and 2014? What are the other controlling factors contributing to affecting housing value next to rail transit stations?

2. What has been the impact of existing rail stations on the racial make-up of residents in neighborhoods surrounding rail transit stations for the period between 2000 and 2014? Do rail stations attract more white residents to live next to rail transit stations? What are the other controlling factors affecting these attributes in proximity to rail stations?

3. Do the neighborhoods immediately proximate to rail transit stations experience change in population density for the period between 2000 and 2014? Also, what are the most important controlling factors affecting population density in neighborhoods surrounding rail stations?

Chapter 2

Review of the Literature

This chapter includes a review of the theories and empirical literature upon which this study is built on. The first two sections discuss the main concepts and history of urban rail transit systems in the United States. The third section covers the major significant factors controlling the impact of rail transit stations on the surrounding areas, meaning the theories behind the causes that may contribute to or affect the research questions (dependent variables). The fourth body discusses the rich and well-developed empirical studies regarding the impact of proximity to rail transit stations on housing values, income, race, ethnicity, and population density in the area surrounding rail stations. A large number of studies have looked at these impacts, and their findings are mixed. Thus, these mixed results show the importance of carrying out the present research study.

2.1 Public Transportation Concepts

Public transportation or public transit is the collection of alternative travel modes that are available for residents, and includes buses, commuter rail, light rail, and heavy rail systems (American Public Transportation Association [APTA], 1994). Public transportation is a transportation system where commuters are carried as groups based on specific times, schedules, fixed paths, and certain prices (Mass Transit, 1998). Mass transit primarily is divided into two types: "fixed route," which operates on rails such as commuter rail, light rails, and heavy rail systems. The second category is the "non-fixed route," where public transportation, like buses, shares roads with automobiles (Mass Transit, 2008). In the United States, public transportation can be categorized as either "large rail," where most of the system is laying on rail, "small rail," in which a few transportation systems are dependent on rail, and the third type is the "bus system," which shares the streets with cars (Litman, 2004).

The most common types of urban rail transit in the Unites States are commuter rail, light rail, and heavy rail systems (Lewis & Hall, 2011). Commuter rail usually serves suburban commuters and moves them to central business districts (CBD). This type of transit can be considered as many-to-one, meaning there are many origins going to one destination. The other two transit types serve as many-to-many, meaning there are many origins going to many destinations. So, commuter rail transit has few stations,

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while both heavy and light rail systems may have more rail stations. APTA (1994) defines the three types of urban rail transit systems as:

- Commuter rail: "Railroad local and regional passenger train operations between a central city, its suburbs and/or another city. It may be either locomotive-hauled or self-propelled" (p.22). This type of transit also called suburban rail.

- Light rail: "An electric railway with a 'light volume' traffic capacity compared to heavy rail. Light rail may use shared or exclusive rights-of-way, high or low platform loading and multi-car trains or single cars" (p. 23). This type of transit has various forms including trams, trolleys, and streetcars.

- Heavy rail: "An electric railway with the capacity for a 'heavy volume' of traffic and characterized by exclusive rights-of-way, multi-car trains, high speed and rapid acceleration, sophisticated signaling and high platform loading" (p. 23). Heavy rail has various forms such as metropolitan railway (Metro), subways, and elevated railways.

Many planners assert that rail-based public transit has more advantages over bus transit. Rail transit systems may change and guide land use forms and development patterns in more efficient and sustainable ways (Black & Lane, 2012; Pacheco-Raguz, 2010). It may also attract more riders since it provides better service quality (Currie, 2005; Tennyson, 1989). For example, when Tacoma City replaced the free bus line with the light rail system, the number of daily riders increased from 500 to 2,400 (Litman, 2012). In addition, rail transit can carry more riders than the bus (Litman, 2012); the capacity of one bus equals 60 private automobiles, while a light rail transit is equivalent to 125 cars (APTA, 2002). Moreover, a light rail system becomes a more attractive public transportation option since it can provide higher capacity, frequency, comfort, and dependability (Cervero, 1984; Kim & Ulfarsson, 2012). Finally, rail transit requires less land per peak passenger-trips, produces fewer emissions and noise, and gains more support from the public. For the most part, bus service cannot provide all these advantages (Litman, 2012; 2015; Pascall, 2001).

2.2 History of Rail Transit System in the U.S.

The earliest form of public transportation in the U.S. was horse-drawn cars, which were established in New York City during the 1830s (Garrett, 2004). Horse-drawn carriages could accommodate around 30 passengers and were pulled by a horse (Golub et al., 2011). Then, this type of streetcar expanded to Philadelphia in 1831, Boston in 1835, and Baltimore in 1844 (Garrett, 2004). However, horsecars were very slow, bumpy, and shared street space with pedestrian and carriage traffic. So, by 1850, placing horsecars on rails was the next advance of public transportation and is considered as the earliest form of light rail transit in the U.S. Laying horsecar on rails increased passenger comfort, the speed of the horsecar, the number of riders, and reduced travel time (Golub et al., 2011). Thus, operation costs declined, resulting in a decrease in fares that led to a major increase in the number of horsecars systems in the U.S. (Garrett, 2004). The next improvement was in 1860, when cable cars were introduced, but the operation of this type was more expensive than horsecars, so it did not prove to be a viable option (Golub et al., 2011).

By 1880, electric streetcars were introduced instead. The power for these streetcars was drawn from overhead electric cables. The operation was much lower than the operation of cable cars and horsecars. Also, electric streetcars were faster and much cleaner than older transit modes. Despite the major improvement in rail transit in the 1880s, all of these rail transit systems could not alleviate traffic congestion, especially since these public transit systems did not have a separate right of way and they operated among other roadway traffic. As a result, heavy rail transit was introduced in late 19th century. The fact that these first systems operated with right-of-way helped pave the way for the U.S to become one of the best countries around the world in terms of its rail transit system in the early 20th century (Garrett, 2004). However, the invention of the automobile, followed by a rapid increase in dependency on private automobiles in the United States, led to a decline in the demand for rail transit systems, which also negatively affected the funds for those transit systems (Garrett, 2004).

In the 1960s, a large number of North American cities saw a resurgence of rail transit investment and many cities started to build modern rail transit systems to mitigate the negative impacts of automobiles, such as traffic congestion and pollution, and to spur economic growth (Garrett, 2004; Golub

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et al., 2011). In 1978, the first modern light rail system in North America was introduced in Edmonton, Alberta (Canadian Urban Transit Association, 2005). Since then, several cities have invested in modern rail transit systems including some car-based cities (Heilmann, 2014).

2.3 Theories and Literature Review Related to Research Questions

The research questions of this study are mainly related to the impact of proximity to rail transit stations in the Dallas-Fort Worth (DFW) metropolitan area on selected socioeconomic and spatial factors. Not only proximity to rail transit stations, but also many other explanatory variables, may contribute to affect housing value, demographic compositions, and population density in neighborhoods near rail stations. Therefore, the sections below explain, in depth, the theoretical arguments that lead scholars to hypothesize that relationships exist between the socioeconomic and spatial factors to rail transit stations. This is followed by sections covering the well-documented literature and empirical studies about different impacts of rail stations on adjacent areas. Since this study looks at the impact of rail transit systems in the DFW metropolitan area, it will only review the prior work that has been done in the United States.

Theory plays a key role in all research projects. Having a full understanding of the significance of theory, particularly theories related to the research topic, is considered as one of the major research processes (Ferman & Levin, 1975). The theoretical framework can be defined as a gathering, describing, and explaining interrelated concepts about the study, and investigating their relationships with each other (Jones, 2010). Yiannakis (1989) suggests that "Research that is not theoretically informed, not grounded in the existing body of knowledge, or of the 'shotgun' variety that fails to raise and investigate conceptually grounded questions, is likely to generate findings of a narrow and ungeneralisable value" (p.6). Literature review shows the major area of knowledge we are dealing with and the contribution of different authors; also, it shows how this research and its contributions relate to the prior work and how it becomes a new and significant contribution. Rowley and Slack (2004) state that literature reviews distill current studies in a topic related to the field of study, and the main aim of the literature review is to summarize the state of the art in the topic related to the area of study. In addition, investigating previous work helps to identify the prospective research in the study area (Rowley & Slack, 2004).

2.3.1   *Theories and Empirical Studies about Changes in Land Value*

This section includes a review of theories and the rich literature about the relationship between transportation, social, economic, and spatial factors that contribute in affecting property value. The theoretical background section is categorized based on explanatory variables that are expected to affect residential land value in proximity to rail stations, meaning the theories will be categorized to theories about changes in residential land value due to proximity to transportation access, proximity to other land uses, proximity to amenities and disamenities, demographic compositions, and population density. However, the literature review section is categorized based on the Census Regions of the U.S., starting from the west toward the east. After that, a list of major factors affecting residential land value will be listed and will be used in the analysis process.

2.3.1.1 Theories about changes in residential land value

a) *Theories about changes in residential land value due to proximity to transportation access*

Bid rent theory, developed by Von Thünen (1863), and later improved by many scholars, can be considered the best model to explain the relationship between transportation and land use and value (McCann, 2013). Von Thünen showed that most productive activities compete for farmlands in proximity to a central market because of better accessibility to the marketplace and the lower costs of shipping agricultural products. Therefore, the demand for agricultural properties in proximity to the city center increased resulting in an increase in agricultural land rent (McCann, 2013). In other words, improved accessibility to the city center is associated with lower transportation costs and higher land value.

Many scholars such as Alonso (1964), Muth (1969), and Mills (1972) have developed a modern version of Von Thünen's monocentric model, and they applied it to urban land uses (McCann, 2013). Alonso's monocentric model adopted largely the same basic approach of the Von Thünen model, but it allowed substitution between land and other production or consumption factors. The main idea of Alonso's theory is that rent increases in proximity to the city center and declines with distance from it because of better accessibility and increased location advantage. Furthermore, several large cities have some multiple urban cores in the outer rings of the city, which are so-called subcenters. Accordingly, the bid rent model can be applied to those subcenters, meaning the proximity to subcenters may play an

instrumental role in increasing land value since those subcenters can be viewed as remarkably similar to a traditional CBD (Luo & Wei, 2005; McMillen, 2004).

The Von Thünen and Alonso models can provide the basis for expecting that rail transit systems may influence property value and promote more development around stations because of a noticeable reduction in commuting and time savings costs generated by better accessibility associated with rail transit. Thus, land value and rents near rail transit stations rise with proximity to the stations and decline with the increasing distance from rail stations (Dawkins & Moeckel, 2014; Debrezion et al., 2011; Kilpatrick et al., 2007; Nembhard, 2009). However, there may be a negative impact resulting from the negative externalities associated with rail transit systems such as unpleasant noise, vibration, pollution, traffic congestion, and increased crime rates (Bowes and Ihlanfeldt, 2001; Hess & Almeida, 2007; Weinberger, 2001b). In addition, those negative effects can attract undesired populations and sometimes overcome the positive effects, which lead to a major reduction in property value.

Another transportation investment that can also increase accessibility is highway systems, which make some areas suitable for residential and other activities. Highways play significant roles in the location decisions of firms and individuals. Firms prefer to locate around highway interchanges and feeder roads, while residential developments tend to locate in the areas with higher accessibility to feeder roads, employment and shopping centers, and recreational opportunities (Gamble & Davinroy, 1978). As a result, the improved accessibility generated by road systems is associated with price premiums for commercial, industrial, and residential properties, which means land buyers purchase accessibility benefits. In other words, the future savings in commuting time and costs will be transferred to the present increase in property value (Gamble & Davinroy, 1978). In short, transportation improvements may increase the demand for land in the area around highways which increase property value (Perera, 1990), and the highest premium would be on the properties near interchange sites since they are the most desirable locations (Carey & Semmens, 2003). However, not all previous work shows an increase in properties values due to negative externalities associated with roads such as noise, pollution, and safety hazards, which may effectively cause declines in property value (Carey & Semmens, 2003).

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b) *Theories about changes in residential land value due to proximity to other land uses*

Transportation accessibility can play a major role in residential property value; however, other important factors may also affect residential land value more than transportation accessibility. The theoretical framework below describes how various land uses influence residential land value.

Based on the bid rent theory, commercial property owners, for example, are willing to pay the highest rent to be located in the city center since it is the most accessible location to the marketplace and highly populated (Bluestone et al., 2008). However, households may purchase housing properties far away from the city center since they do not rely heavily on the marketplace and can afford the reduced costs (Bluestone et al., 2008). The impact of non-residential uses on residential land value may be either positive or negative (Burnell, 1985). Any commercial use has a major advantage related to convenience, particularly in commuting and time cost savings. Thus, as the distance to commercial use decreases, the commuting costs and time also decreases, and thereby, residential land value increases (Loehr, 2013). However, another theoretical concept predicts that residential land value falls with proximity to commercial land uses due to negative externalities resulting from such commercial uses like pollution, traffic congestion, and noise (Miller, 1999).

In the ancient Greek and Roman communities, residential, commercial, retail, and industrial land uses were within the city walls (Wright,1967); however, with the invention of the private automobile and changes in cultural behavior co-location, land uses began to be segregated (Grant, 2004). In the ancient communities, land use types were similar to the more recently defined term of "mixed land use." This can be defined as a mixture of various land uses such as commercial, retail, residential, and office uses within a certain area and within walking distance (Aurand, 2010; Song & Knaap, 2004). Mixed land uses can have positive and negative external effects on housing prices (Loehr, 2013; Song & Knaap, 2004). Such land use exhibits positive impact on adjacent residential property prices due to convenience and increased accessibility, which allows residents to do all daily activities within walking distance and results in major savings in commuting time and costs. On the other hand, it is also associated with some negative externalities that sometimes outweigh the convenience of nearby land uses (Li & Brown, 1980; Mills, 1979; Song & Knaap, 2004).

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Transit stations developed as a TOD involve a form of mixed-use development with moderate to high density, and they are designed to encourage people to bike and walk in the area adjacent to rail stations (North Central Texas Council of Governments [NCTCOG], 2011). According to Mathur and Ferrell (2012), "Economic theory suggests that people are willing to pay a premium for access to amenities, ceteris paribus. These amenities get capitalized into the value of the property that supports such activities" (p, 43). So, TODs are a highly desirable amenity to residents which in turn increase residential land value. However, TOD sometimes generates disamenities such as increased noise, vibration, higher crime rates, air pollution, and traffic congestion, which would likely depress residential property value. Industrial land uses, however, are associated with several negative externalities. Accordingly, proximity to industrial sites has an adverse impact on housing value which diminishes with greater distance (De Vor & De Groot, 2011). Zoning ordinances may minimize negative externalities by separating different land uses from one another. For example, buffers, walls, setbacks, and planting tall trees can separate homes from some nonresidential uses (Matthews, 2006).

c) *Theories about changes in residential land value due to socioeconomic attributes of residents*

The residential property value in many U.S. cities is spatially differentiated by income, race, and household job (Schill & Wachter, 1995). Ottensmann (1977) explains that income is one of the main driving forces behind housing value and population density. The bulk of valued amenities in some neighborhoods is positively associated with property value. Therefore, wealthier households are attracted to those communities, and housing demand will increase resulting in higher land value and displacement of low-income residents. As a result, low-income residents are forced to relocate in areas far away from high-income neighborhoods (Freeman, 2005; Nembhard, 2009).

Galster (1982) pointed out that race also had a strong relationship with income in various ways, meaning that white people are usually wealthier than African-Americans, Hispanics, Latinos, and other ethnic groups. Bingham and McMichael (1923) state that "Neighborhoods populated by white persons have been invaded by colored families, and often aristocratic residential districts have suffered tremendous lessening of property values because of the appearance of a Negro resident." (p.370). Accordingly, non-white residents are linked to property devaluation. Whites reject purchasing houses in

black neighborhoods, which leads to lower demand for properties, and thereby cutting the number of potential competing bidders, so land value declines (Armstrong, 1997). In short, wealth is usually associated with white people, and higher-income residents increase residential property value, while non-white residents decrease the residential land value.

In addition, income is associated with employment level; workers with higher income prefer to reside close to their workplace. Consequently, the increased demand for residential properties in proximity to workplaces results in an increase in land prices. Moreover, higher-income employees prefer single-family housing units with large lot size, which may lower the density of development (Ottensmann, 1977). However, unemployment rates have a strong negative relationship with residential land value (Pinter, 2015). Spencer (1969) shows that lower unemployment rates increase housing value rapidly, whereas rising unemployment level decreases housing value slowly. The unemployment level is not a direct determinant of land value, but the rate of unemployment affects residents' income, and thereby, housing value.

d) *Theories about changes in residential land value due to proximity to amenities and disamenities*

Residential property value is not only affected by physical characteristics or better accessibility but value is also influenced by characteristics determined by location such as amenities and disamenities (Cheshire & Sheppard, 1995). The modern urban theory about market behavior applies the traditional urban economic theories to consider locational preference despite the importance of accessibility. This means land value depends not only on better accessibility, but also on the interaction between amenities, disamenities, and location characteristics relative to a series of urban goods and services (Berry & Bednarz, 1979).

Amenities and disamenities are usually excluded when estimating residential land value whereas they have direct impacts on resident utilities. They become important factors in people's decisions and can impact land value either positively or negatively (Chen & Jim, 2010; Song & Knaap, 2004). The major benefit of amenities is associated with population convenience, specifically in commuting cost and time savings that result in better quality of life, so as the number of amenities increases in a specific neighborhood, the demand for land increases, and thereby, higher residential value result (Chen & Jim,

2010; Cheshire & Sheppard, 1995; Gardner, 2007). Also, the ability to reach some amenities within walking distance raises property value, and increases dwell time in the area (Gardner, 2007). The most common amenities are lakes, parks, recreation areas, open spaces, residential gardens, mixed land use, educational institutions (schools, universities), shopping malls, rail transit stations, and employment locations (Chen & Jim, 2010; Cheshire & Sheppard, 1995; Song & Knaap, 2004). However, disamenities can affect residential land value negatively. They include landfills, waste sites, nuclear power plants, manufacturing and industrial facilities, air and noise pollution, and increased crime rates (Cheshire & Sheppard, 1995; Song & Knaap, 2004). Some amenities may sometimes become disamenities when the negative externalities exceed the benefit of the purpose of the service. For the purpose of this study, the focus will be on the major amenities that can increase the attractiveness or value of locations, which in turn, affects housing value including parks, schools, and shopping malls.

In theory, the major benefits of parks and open spaces can be either passive use benefits or active use benefits. Passive use benefits are the pleasure of a location being conserved, while active use benefits include recreational use, scenic views, privacy, and use as a barrier to neighboring developments (Breffle et al., 1998). Also, passive use benefits are non-rivalrous, meaning that no one can preclude another from enjoying the preservation of open spaces. Conversely, active use benefits are rivalrous, meaning that living in proximity to a park or open space prevents others from enjoying the same benefits such as privacy, recreational opportunities, and scenic views. Since the active benefits are rivalrous, landowners will raise the value of residential lands in the areas near parks and open spaces (Weigher & Zerbst, 1973). In short, parks and open spaces have a positive impact on real estate value; however, the magnitude of effect depends on the proximity to residents, the size of the area, and the density of development (Bartholomew & Ewing, 2011).

Urban economists have long recognized that schools play a significant role in the decision of choosing a home location and the demand for area housing (Tiebout, 1956). Educational institutions can be viewed as a boon or a nuisance to a residential neighborhood. The demand for properties closer to schools is higher because of better accessibility and more safety. As a result, the increased demand could lead to significant price premiums in residential property value. By contrast, schools may cause

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external disamenities to spill over into the adjacent area. For example, speed restrictions, traffic congestion, and noise from playgrounds are negative externalities that may affect adjacent properties to schools negatively (Colwell & Guntennann, 1984; Hendon, 1973). Moreover, shopping malls, major employers, and subcenters can have positive or negative external effects; these can have simultaneously attractive and repulsive effects leading to changes in residential land value and choice (Addae-Dapaah & Lan, 2010; Des Rosiers et al., 1996). For instance, they can be a source of positive externality when providing convenience to neighboring residents such as savings in commuting time and costs and increased accessibility. In contrast, they can be a source of negative externalities that disturb neighboring residents.

e) *Theories about changes in residential land value due to population density*

Bid rent theory suggests that the city center is valuable for some land uses since it is the most accessible location for most people in the city (Bluestone et al., 2008). Consequently, the farther the distance from the CBD, the cheaper the land. This is why city centers are very densely populated, while suburbs and rural areas are more sparsely populated, with detached houses and relative low density (Bluestone et al., 2008). In addition, as landowners are willing to compromise the higher price of land in CBDs, they allow for higher densities by allowing many housing units on each parcel of land (Berry, Simmons, & Tennant, 1963). Based on the land conversion theory developed by Bockstael (1996), the higher land value can be an incentive for landowners and developers to seek the highest and best use to offset the increased land value so that some land uses will be converted to other uses with higher density. In addition, in compact development areas that have moderate to higher development density, households can perform all daily activities within walking distance. As a result, the increased desire for compact development leads to more demand for residential units in compact development, which increases in land value (Koster & Rouwendal, 2012).

2.3.1.2 Empirical studies on the impact of rail transit stations on property value and rent

Over the past two decades, a considerable body of literature has emerged that evaluated the impacts of rail transit system on the adjacent neighborhoods with varying results. These studies have estimated the consequences of proximity to rail transit systems on residential, commercial, office, and

industrial properties values, and looked at different rail technologies such as light rail, heavy rail, and commuter rail. Yet, the vast majority of the existing studies focused on residential properties, especially single-family housing, and most of them revealed significant price premiums for rail station proximity, while a few found an adverse impact. The following summarizes most of the existing studies in the United States that examined the impact of rail transit systems on residential properties value and rent to see the contribution of different authors, and how this research study relates to the prior work.

The interest in examining the impact of urban rail transit systems on land values in the U.S. began to appear in the early 1970s, when the building of passenger rail transit systems began in earnest (Giuliano, 1989). Perhaps the most widely studied are rail transit systems in California (e.g. BART, CalTrain, Sacramento LTR, Santa Clara LTR, San Diego Trolley, MetroLink, and Metro LA). In particular, BART is the rail transit system that has been most extensively studied by many researchers; this system began service partially in 1972, and was completed in 1975 (Landis et al., 1995). The earliest study was done by Lee (1973) with mixed results. Then, the five subsequent studies (Baldassare et al., 1979; Dornbush, 1975; Dyett et al., 1979; Burkhardt, 1976; Webber, 1976) concluded that BART stations affected nearby residential land value negatively and that people did not prefer to live in proximity to stations due to greater negative externalities associated with rail transit systems (Clower & Weinstein, 2002; Landis et al., 1995). In addition, most of the follow-up studies found mixed findings regarding the impact on housing land value in proximity to BART stations. A study conducted twenty years after BART began operating investigated the impact on single-family homes within 300 meters from rail stations and concluded that with the improved accessibility that results from BART stations, the average housing value showed an increase. With each meter closer to a rail station, the property value increased, ranging between $1.96 to $2.29 (Landis et al., 1994).

In addition, Landis et al., (1995) conducted a study to examine the impact of five rail transit systems across California on residential property value within 300 meters radius around stations. The rail systems investigated are BART, CalTrain, Sacramento, Santa Clara, and the San Diego Trolley. Authors used the hedonic price model to estimate the impact of transit stations on property value. It found that rail transit had a weak and not consistent impact on residential land value in all five-rail systems since the

distance to transit stations and highway ramps were not statistically significant. The study showed that the highest increase in single-family housing value was found within heavy rail stations (BART and CalTrain), while homes close to light rail stations, freeway interchange, and neighborhoods dominated by Hispanics, blacks, and Asians experienced a decline in the price. In addition, lower noise generated by rail transit systems, better services provided, more parking capacity, greater speed, and more frequent service increased residential land value slightly; whereas, homes near right-of-ways experienced sharp declines in price. Almost similar results were found when Cervero and Duncan (2002b) examined the impact of different rail transit systems (heavy rail, commuter rail, and light rail) in Los Angeles County on various land values, including single-family, multi-family housing, condominiums, and commercial properties. This study estimated with hedonic price models the impacts of rail transit system on roughly 60,000 properties within half a mile from stations. The findings showed that property values within areas surrounding rail stations were uneven and inconsistent, with both positive and negative impacts recorded. Prices of condominiums and single-family housing experienced a major decline compared to multi-family buildings. The reduction was greater next to heavy rail or light rail stations, but condominiums and single-family housing units experienced higher values than multi-family units did when being close to the commuter rail stations.

In addition, Cervero and Duncan (2002c) did a similar study to examine the impact of different rail transit systems serving San Diego County on values of around 26,000 different types of properties. A one-half mile radius around stations within South Line, North Line, East Line, Mission Valley Line, and one-quarter mile radius with Downtown Line were identified to examine the impact on property value. The study showed significant variation in findings in both signs and magnitudes. In the area surrounding Coaster commuter rail stations, single-family housing had an average value premium of 17%, and a small increase in price next to South Line stations, 0.6%, while single-family property values next to East Line and North line stations depressed by 1.6% and 4.2% respectively. In this study, the factors most affecting land value, either positively or negatively, were proximity to rail stations, proximity to freeway ramps, household income, housing and employment densities, and the number of white residents.

Duncan (2008) also tested the impact of rail stations on the values of single-family housing properties in San Diego. A hedonic price model was been used to examine the impact of transit on 139,000 homes located within one network mile of stations. The study concluded that the value of single-family housing within one-quarter walking mile from stations increased by 6%, meaning housing units within one-quarter walking mile from a station was worth almost $12,000 more than housing units within one mile from stations. Most of the independent variables included in the equation were significant, in particular the distance to rail stations, which had a negative coefficient. However, proximity to open spaces and freeways, household income, and education level were not statistically significant. Finally, denser area or TOD area experienced higher capitalization benefits than areas that had only single-family housing units.

In San Jose, CA, Mathur and Ferrell (2013) examined the impact of the Ohlone Chenyoweth station, developed as a TOD, on single-family homes within one-half mile buffer between 1991 and 2006. This study used three hedonic regression models for three different periods to estimate the effect on home prices. The study finds that all variables are statistically significant with expected signs. The major findings showed that homes within one-eighth mile from the station went up by 18.5% more than housing beyond this distance. In addition, beyond a one-eighth mile, the effect on housing land value was not statistically significant and began to dissipate. However, some other factors found affecting housing value negatively were proximity to freeway, higher population density, and a greater number of non-whites.

Over the past two decades, the Metropolitan Area Express (MAX) rail transit system in Portland has received considerable attention from scholars. Yet, current studies have produced mixed findings when examining the impact of rail stations on residential property values. Shortly after the light rail system began operation, Al-Mosaind et al. (1993) analyzed the impact of Portland's MAX light rail stations on single-family homes within 500-meter buffer around stations. Two hedonic price models were applied and compared. The first was for property values within 500 meters from stations, and the second was for properties between 500 meters and one kilometer from rail stations. The study found a modest positive effect only within a 500-meter buffer, meaning properties within 500 meters experienced an increase of 10.6%, while properties beyond that declined by $2,175 for every 100 meters farther away.

After the work of Al-Mosaind et al. (1993), Chen et al. (1998) attempted to study the impact of both light rail stations and the rail line itself on single-family homes value within a 700-meter buffer. In this study, authors applied more independent variables than Al-Mosaind et al. (1993) and used the hedonic price approach. The analysis showed that building attributes and distance to station was statistically significant, while distance to the rail line right-of-ways, distance to the nearest park, and the distance to CDB were insignificant. The study found that the value of the single-family home increased with a shorter distance to rail stations. In other words, within the first 100 meters, housing units experienced value increases. However, beyond that, the value decreased by $32.20 for each additional meter. Moreover, proximity to parks increased property value, while proximity to the Portland CBD did not have any impact, and proximity to the rail track impacted land value negatively up to 215 meters from rail line. A similar study also was done by Knapp et al., (1996) to examine the impact of MAX stations on single-family housing values within one-half mile. The findings showed that properties in proximity to rail stations increase with shorter distance to stations; however, the rail line depressed property values adjacent to tracks, but not close to a station. This was because of some negative externalities associated with rail lines such as noise, pollution, and unattractive views.

Another study of the Portland MAX done by Lewis-Workman and Brod (1997) examined the impact of Eastside Portland MAX corridor on single-family housing; the hedonic approach was utilized to examine 4,000 housing properties within one-mile radius from three rail stations. The study indicated that property values are lower within the first few blocks of the stations, but they increased by roughly $2.49 for every meter closer to a station within the distance between 762 to 1609 meters from stations. However, proximity to rail tracks and to a highway affected single-family housing value negatively. For the Westside Portland MAX corridor in particular, Dueker and Bianco (1999) examined the impact on single-family value for the period before opening the LRT and after ten years of operation. The major findings of the study showed that single-family home values increased by $2,300 within the first 200 feet from stations, but the values declined by 5%, 2%, and 1% when located at 400, 600, and 800 feet farther from LRT stations, respectively.

While most of the case studies discussed in the previous section involved cities in the Western United States, there is also an abundance of additional interesting case studies in the Northeast region, where older metropolises and rail systems are located—which will be covered in this section. The most significant rail transit systems that have been studied are those in Philadelphia, Washington D.C., Boston, Buffalo, New Jersey, and New York City. One of the first studies on the impact of rail transit on property value examined the impact of the Lindenwold commuter rail line in Philadelphia on residential property value. The study concluded that the reduction of commuting costs and time resulting from the proximity to rail stations generated an increase in residential properties values. The average residential land value was $149 for each dollar saved in travel cost. The impact was more apparent in residential properties in low and middle-income communities due to the importance of transit accessibility to them (Boyce et al., 1972). Later studies also investigated the impact of proximity to the Lindenwold rail stations on housing land value and found similar results. One study found that houses around rail stations increased in value by 7%, or $4,500 per home (Rice Center for Urban Mobility Research, 1987). Another study used 571 census tracts in areas next to rail stations in Philadelphia. This study utilized the hedonic price model and found that accessibility to rail stations was the most significant factor affecting housing value; it generated an average housing value premium of 6.4%, or $5,716 per property (Voith, 1993).

On the East Coast of the U.S., the Washington D.C. Metro has been widely studied by many scholars. One of the earliest studies was before the construction of the rail system (Damm et al., 1980), which investigated the preservice impact of the Metro on single and multi-family housing for the period between 1969 and 1976. Authors used regression models and found that the most significant factor affecting property value positively was the proximity to rail stations. The following work done by Donnelly (1982), also before the operation of the rail transit, found that new rail systems would lead to more decentralization of population and employment and therefore, land value would decline in older neighborhoods located in proximity to rail stations. In addition, Grass (1992) studied the impact of Washington D.C.'s Metro on residential land value within a quarter-mile buffer around stations. To examine the relationships, the hedonic model was used to test the property value in areas surrounding stations and control areas. The control areas had the same characteristics of the study area, but they

were not located near an active or proposed rail station. The main results of the study showed that residential property in affected areas increased by $17,352, or 19%, compared to the control areas. Property characteristics and distance to rail stations were statistically significant, while the distance to the city center were insignificant and did not affect property value.

In Boston, Armstrong (1994) examined the impact of the Fitsburg commuter rail system on 451 single-family property values. The study used a multiple regression model to estimate the impact of rail stations and right-of-way lines on houses within a one-mile walking distance from stations and rail tracks. The author found that structural attributes, distance to rail stations and line, school quality, and crime rates were statistically significant. The study concluded that the value of houses located in census tracts affected by rail stations had average premium increases of 6.7% per house, but homes within 400 feet of the line tracks were devalued by 18.9% of the market prices. In the follow-up study, Armstrong and Rodriguez (2006) estimated the impact of rail stations and rail tracks on 1,860 single-family residential properties within Boston. A spatial hedonic price function was used to find the major factors affecting single-family homes values in the study area, and the authors concluded that homes located in proximity to commuter rail right-of-ways experienced a negative impact. However, as the distance from the rail line increased by 1,000 feet, the value of the property increased between $732 and $2,897. In addition, residential property values within a one-half mile from rail stations were 10.1% higher than properties located out of the identified buffer. However, as the drive time from station increased by one minute, the land value decreased by 1.6%. The major factors found affecting single-family property value positively were a lower commuting time to work, larger structural attributes, and a shorter distance to the highway interchanges. Conversely, heavy traffic streets influenced property values negatively.

In Buffalo, Hess and Almeida (2006) examined the impact of 14 light rail stations on 7,357 single-family properties within a one-half mile straight-line and walking distance. The study found a moderate increase in land value. It concluded that some of the property characteristics and location attributes influenced property value more so than rail proximity. Also, the study suggested that property value increases by $2.31 for each straight-line foot and $0.99 for each walking foot closer to the station. In general, a residential property located within one-quarter mile from stations was valued $1,300 to $3,000

or 2% to 5%, more than the city's median home value. In addition, the study explored how properties within higher-income neighborhoods experienced higher premiums, while properties within lower-income station areas were devalued.

In another study, Kay et al. (2014) evaluated the impact of eight rail stations on residential land value in New Jersey and New York City. Using spatial econometric models to examine housing value within a two-mile radius. The major findings of the study showed that block groups in proximity to rail stations had higher land value. For example, block groups within one-half mile from stations had a value that was 6.3% to 9% greater than block groups within a one-mile and 1.5-mile buffer. In addition, as the household income increased by $10,000, the land value increased by 2.5%. Furthermore, proximity to schools and parks affected residential land value positively. However, the higher number of blacks and minorities impacted property value negatively. Population density and crime rates did not have any impact on residential property value.

A large number of Sunbelt cities in the Southern region, such as Miami, Atlanta, and Dallas, and Phoenix in the West, have experienced rapid growth in population and have begun to invest in rail transit systems. Gatzlaff and Smith (1993) looked at the impact of Miami Metrorail stations on the value of 912 single-family housing properties. The study compared values around rail stations in the entire county for the period between 1971 and 1990. It used a hedonic regression model to evaluate the differences in residential land value before and after the announcement of the rail system. The findings indicated that the impact on residential land value was generally very weak; however, stations located in the north part of the city affected residential land value negatively, while southern stations create housing value premiums to increase. Furthermore, not only did proximity to stations affect residential land value, but also other factors played a major role in residential land value including some social and economic factors, property types, and neighborhood characteristics. For example, high income and low crime rates in neighborhoods had a weak positive impact, while in low-income communities, there were no changes, and housing declined in value in neighborhoods with high crime rates.

In Atlanta, some researchers also came to the same conclusion, meaning MARTA had a weak or virtually no impact on the value of housing units (Nelson & McCleskey, 1989). Nelson and McCleskey

(1989) used a hedonic regression model to examine the effects of three elevated stations on the value of housing within a one-half mile from stations. The study found that proximity to rail stations had no impact on residential land value due to some negative externalities associated with rail transit. In another study conducted by Nelson (1992), a similar section of the MARTA line was used to determine the impact of rail stations on 286 homes in both high income and low-income neighborhoods located within a one-half mile radius around stations. The study discovered that transit stations had a moderate impact on sale prices of single-family homes. For example, homes in low-income neighborhoods increased by $1.05 for each foot than the home was closer to the station; whereas the value of homes in high-income neighborhoods was depressed by $0.96 for every foot in proximity to stations. Furthermore, a study by Bowes and Ihlanfeldt (2001) investigated the impact of MARTA rail stations on the value of 22,388 residential properties. This study examined the impact of stations by applying hedonic regression models to determine the impact on residential land value. The findings suggested that the land value of properties located in high-income neighborhoods between a one-quarter mile to three miles of stations increased sharply, with the highest increase in value found in properties within a one-half-mile to one-mile buffer from stations. However, the value of residential properties within a quarter mile of stations, in proximity to the downtown with parking lots declined by 19% since parking lots were perceived to increase crime rates in the area surrounding stations and rail transit could produce a higher level of noise.

In Dallas, Weinstein and Clower (1999) conducted a study to estimate the initial economic impact of the DART system on the property values between 1994 and 1998. A matched pair technique was used to estimate the effect of 15 DART stations and a control area on land value of residential and other different land uses. Around 700 residential and commercial properties within a one-quarter mile buffer around rail stations were examined and compared to 160 properties in similar locations that were not affected by DART stations. The authors concluded that residential properties experienced a value increase of 6% in station areas and a devaluation of 2% in non-station areas. Clower and Weinstein (2002) then expanded their earlier work by considering properties within a one-quarter mile buffer around 23 DART stations to analyze the land value of single and multi-family residential and other land uses. The study used the matched pair technique and excluded stations in the Dallas CBD. The results showed that

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the value of single and multi-family housing increased by 38.2% and 42% respectively compared to 20% and 34% in non-station areas. A follow-up study by Clower et al. (2014) expanded and updated the previous two studies. This study analyzed both properties within a one-quarter mile radius from rail stations and properties beyond the established buffer. The findings showed that new developments located within one-quarter mile of rail stations totaled greater than $1.5 billion collectively in valuation between 1993 and 2013, while in the control area, the value was only around $600 million. Moreover, single and multi-family residential housing in the station areas totaled $751 and $141 million, respectively, but it in the control area, the development values were a mere $170 and $67 million.

Only a few studies published on the impact of DART stations on residential land value used regression models. Leonard (2007) examined the impact of 23 DART stations on 18,164 properties within 3,000 feet from rail stations. The rail stations in downtown Dallas were excluded since there were some external factors affecting land value other than the rail transit system. The findings showed that housing properties close to railways experienced an adverse impact. The average devaluation ranged between $50 to $104 for each 30 feet closer the rail transit line. However, residential properties in proximity to stations experienced a positive impact, and the average value increase ranged between $31 to $77 for each 30 feet closer to the station. Another study done by Smith (2011) examined the impact of DART stations on property values within a one-quarter mile from rail stations between 2001 and 2008; two TODs, Addison and Plano stations, were analyzed with Richardson as the control site. The study concluded that property value increased in areas surrounding the Plano station up to a one-mile buffer, while at the Addison station, the positive impact was only within the first quarter mile radius. However, proximity to the highway declined land value in Plano and Addison stations, while property value in Richardson increased with the proximity to highways. Another study used regression models to examine the changes in housing values within 59 mixed-use census tracts located within a one-half network mile from stations that were developed as TODs in the DFW metropolitan area (Mandapaka, 2012). The study concluded that median housing value grew by roughly 50% or $67,000 in the period between 2000 and 2009. The major variables explaining the variation in housing value and influence on the value positively were the increased residential, office, retail, and mixed uses; proximity to parks; proximity to schools; and

employment locations. However, other variables affected housing value negatively, including distance to the downtown and distance to highway ramps.

In Phoenix, Atkinson-Palombo (2010) examined the effects of the LRT system, which began operation at the end of 2008, on single and multi-family residential value. Hedonic price models were used to analyze the influence of stations on all parcels of land within a half-mile walking distance from stations. The study found that the effects varied by housing and neighborhood type. Single and multi-family units in amenity-dominated mixed-use neighborhoods that were treated with walk-and-ride stations experience increased value premiums of 6% and 20%, with an increase in value by 6% and 37%, respectively, after the announcement of the overlay zoning. In sharp contrast to these price increases, single-family and multi-family neighborhoods where rail stations had park-and-ride facilities experienced adverse impacts on value. Also, other factors could lower single-family housing value such as higher traffic, noise, and congestion generated by the parking lot. However, the denser areas such as mixed-use and multi-family housing that had fewer parking lots were expected to increase value. Golub et al. (2012) conducted a study to explore the effects of Phoenix's light rail stations on single and multi-family housing values. The study covered a two-mile buffer around stations and tracks for several stages from the planning process beginning in 1999 to the first operational year, 2008. Using a hedonic regression model, the study found that proximity to the airport and rail tracks affected single and multi-family property values negatively, while proximity to the CDB and rail stations had a positive impact on the value.

2.3.1.1 Summary

Based on the literature, it can be concluded that many economic and social theories explain the factors influencing land value in general and residential land value in particular. The major factor impacting land value is increased transportation accessibility, including better accessibility to the center of the city, to rail stations, and to highway interchanges. Not only does better accessibility affect residential land value, but numerous other factors may also play a major role in determining land value such as structural characteristics, proximity to amenities and disamenities, urban development patterns, different land uses, population density, and socioeconomic characteristics of residents such as household income,

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race, ethnicity, education, and employment status. These factors can affect residential land value positively, although negative externalities may negatively influence property value as well.

Even though there are large numbers of published studies about the impact of proximity to rail stations on residential property value, the results of these studies vary widely based on transit system type, geographic area, methods used, and some socioeconomic factors. Nevertheless, the majority of the existing studies concluded that proximity to rail transit stations had a positive impact on residential land value due to better accessibility associated with rail transit systems, while other cases found a decline in residential land value, weak impact, or no significant price effects. In addition, some of the prior work found positive impacts in some stations and negative in others even if the stations were within the same rail system.

Previous empirical studies investigating the impact of rail transit on residential land value used individual housing transactions data as the unit of analysis, while very few used census geographic units such as census tracts or block groups. Of some import to this current study, a good number of previous work applied regression models to estimate the rail transit systems impacts on property value since in part because it is one of the most accurate methods. However, these models did not include enough explanatory variables. Most of the existing studies that have used regression models found the major factors affecting residential land value positively to be proximity to rail stations, proximity to amenities, and site attributes (e.g. lot size, number of bedrooms and bathroom, building age). Yet, being in the vicinity of a rail track or highway ramp decreased residential land value because of unpleasant noise, vibration, and more traffic congestion. Due to the unavailability of data for all factors, this study will be limited to the most common factors that can determine the size of the impacts on housing value and have been used on the well-documented literature that looked at the impact of rail transit systems on residential property value as shown in Table 2-1.

Table 2-1 Major factors that affect housing value

Category	Factors affect changes in residential land value
Transportation accessibility	Distance to closest rail station
	Distance to nearest highway access ramp
Land uses	Residential uses
	Commercial
	Industrial uses
Socioeconomic characteristics of population	Income
	Education level
	Employed residents
	Race
	Ethnicity
Location attributes	Population density
	Employment density
	Neighborhood developed as TOD
	Availability of park-and-ride facilities
	Distance to nearest Downtown
	Distance to closest subcenter or major employment centers
Proximity to amenities and disamenities	Distance to closest school
	Distance to closest shopping mall
	Distance to closest open space and park

2.3.2   *Theories and Empirical Studies about Changes in Socioeconomic Characteristics of Residents*

This section presents a review of theories and existing studies regarding the relationship between transportation accessibility, socioeconomic factors, the housing market, and spatial factors that may affect socioeconomic attributes (income, race, and ethnicity) of residents living in close proximity to rail stations. In the first section, the theoretical background was categorized based on the control variables that may affect socioeconomic attributes of residents within neighborhoods surrounding rail stations. This section will categorize theories about changes in socioeconomic factors due to: transportation accessibility and gentrification, residential segregation due to changes in income, race, and ethnicity, housing market and nonmarket forces, and other factors.

The literature review is categorized based on the type of effect. The first part will be about the existing studies that look at the impact of transit stations on a combination of socioeconomic factors among transit area residents. The second part examines whether rail stations attract high, median, or low-income residents. The third part examines if rail stations are more attractive to white or black residents. The last part focuses on studies that investigate the presence of ethnic minorities in close proximity to rail stations. This is followed by a list of the main factors affecting income, race, and ethnicity of residents in proximity to rail stations since those factors will be used in the analysis processes. It is important to note that studies on the connection between rail transit systems and socioeconomic attributes of residents have not received considerable attention in the academic literature compared to studies about the impact of rail transit systems on residential property value. In addition, the existing studies found varying results as to the association of rail transit systems with income, race, and ethnic groups' distribution.

2.3.2.1 Theories about changes in income, race, and ethnic characteristics

a) *Theories about changes in socioeconomic characteristics due to transportation access and gentrification*

Understanding the relationship between location and land value requires recognizing how much people are willing to pay for the land. Bid rent theory can be applied to rail transit stations since rail stations can resemble the city center, meaning the closer the rail station, the higher the property value. Therefore, only high-income households are attracted to neighborhoods surrounding rail stations and low-income residents are displaced since they cannot pay for higher land value (Dawkins & Moeckel, 2014; Freeman, 2005; Nembhard, 2009). Also, due to better accessibility generated by rail stations, gentrification is spurred and attracts only higher-income households (Kahn, 2007; Lin, 2002), which may alert the residents in the adjacent neighborhoods to rail stations (Dawkins & Moeckel, 2014; Pollack et al., 2010). In short, higher land value, due to increased accessibility and gentrification, may frame issues related to inequity in either race or income level (Pollack et al., 2010).

Lin (2002) found that the presence of rail transit systems and the decline of commuting costs have resulted in a massive gentrification in the center of the city and neighborhoods surrounding rail

stations. The author explained that gentrification is associated with many characteristics including a higher increase in land value, changes in races and ethnic groups, and conversion from multi-family housing to single-family housing. This study also divided these changes into two major categories: changes in real estate market variables (e.g. change in value, renovations, permits, sales) and changes in household variables (e.g. family size, race, ethnicity, income, education). Also, Hammel and Wyly (1996) developed a model to identify gentrified areas; the authors selected some variables to distinguish gentrified areas and to classify central city tracts. Their study tested the changes in socioeconomic variables including household income, working status, education level, changes in housing values and rent, changes in population, and employment status. The model concluded that employment, profession, income, and rent were significant variables in demonstrating gentrification.

b) Theories about residential segregation due to changes in income, race, and ethnicity

Galster (1982) suggested that households were willing to maximize their utility when entering the housing market, but they had to keep in mind that they were constrained by their income. In other words, when households were willing to buy a house, income played a major role in choosing the location and the attributes of the house. These characteristics included structural attributes (e.g. land size, number of bedrooms and bathrooms), location attributes (e.g. crime rates, noise, pollution, population density, racial composition), and neighborhood accessibility (e.g. proximity to workplace, to a highway ramp, and to rail stations).

In addition, Galster (1982) noted that race was strongly correlated to income in various ways. In other words, white people are usually wealthier than blacks, Hispanics, and other ethnic minorities. Moreover, some social scientists investigated the impact of racial segregation on the performance of groups being segregated by income, education, jobs, and poverty level. They found that whites, blacks, and other ethnic groups had some specific choices and preferences that led to racial and class segregation in some communities. Using the self-segregation theory, whites self-segregated into some communities since they preferred to live with members of their own race, and likewise with blacks. Additionally, the preferences for some amenities dictated this self-segregation (Galster, 1982; Ihlanfeldt &

Scafidi, 2002). King and Mieszkowski (1973) added that whites paid less for housing in racially mixed neighborhoods, and blacks paid more for housing in ghettos.

Furthermore, Gabriel and Rosenthal (1989) showed some socioeconomic characteristics that could affect the residential location choice for either black or white residents. The authors suggested that race was the major determinant of residents' housing choices. A higher level of education and higher income also seemed to affect the choices of housing location, but they did not reduce black-white segregation in the housing market. On the other hand, higher education, higher income, and better employment status of some minorities, including Jews, Italians, Mexicans, and Asians, could help them to live in areas not dominated by their own ethnic group (Massey & Denton, 1993). It can be noted that residential segregation creates more homogeneous demographics within neighborhoods (Howell-Moroney, 2005; Tiebout, 1956). It is possible to conclude that poor residents cluster in city centers' old neighborhoods that lack public services, educational institutions, and interactive social effects, but middle and high-class residents move away to suburbs (Riddick, 2014).

Most of the previous work has focused on racial segregation, but little attention has been given to other possible types of neighborhood segregation (Brasington et al., 2015). Other possible forms of segregation are disparity by age group, education, or income. For instance, older people prefer to reside in areas that have some amenities such as senior centers. Some high-income residents are likely to settle in neighborhoods that are close to certain amenities such as parks, open spaces, high-quality public schools, and golf courses. Likewise, highly-educated and high-income households may outbid others to settle in areas that meet their needs and desires. This outbidding causes residential land value premiums to be segregated by race, age, income, and education levels (Brasington et al., 2015). In short, changes in demographic composition within a particular area can be affected by race, ethnicity, education, and income variations of the residents (King & Mieszkowski, 1973; Galster, 1982; Ihlanfeldt & Scafidi, 2002).

c)   Theories about residential segregation due to housing market and nonmarket forces

Other theories state that some housing market and nonmarket forces can lead to differentiation by race and income (Schill & Wachter, 1995). Complex market forces, including the variances in housing demand factors (e.g. income, workplace) and the variances in supply factors (e.g. housing value) may

play a significant role in the racial composition of neighborhoods—resulting in neighborhoods dominated by one specific race (Brasington et al., 2015). Moreover, non-market factors could also affect racial composition of neighborhoods. These factors include discrimination in mortgage and other discriminatory practices such as "steering" in real estate markets (Galster, 1988; Galster & Godfrey 2005; Massey & Denton 1993). Massey and Denton (1993) claimed that despite the Fair Housing Act of 1988, segregation is often perpetuated by individual actions, governmental policies, and institutional practices. For instance, blacks may not be free to choose where they could live since their neighborhoods are built through a series of some institutional practices driven by whites who want to force blacks to live in specific areas inhabited by blacks only (Massey & Denton, 1993). In the housing market, real estate agents use many ruses to prevent blacks and other minorities from living in white neighborhoods, so blacks are usually steered toward "black" areas (Gottdiener & Hutchinson, 2011). Moreover, governmental policies and regulations of subsidized housing programs may also differentiate residents based on race, income, and ethnicity (Schill & Wachter, 1995). For example, federal housing policies direct most of the public housing to the old cores of cities, while whites benefit from housing subsidies in the suburbs (Gottdiener & Hutchinson, 2011).

Because of racial segregation, many poor residents, particularly blacks, are condemned to experience lower education levels, higher unemployment rates, extreme poverty, welfare dependency, higher crime rates, and the prevalence of social and physical deterioration. As a result, the chance of blacks to succeed either economically or socially usually becomes more difficult (Massey & Denton, 1993; Wacquant & Wilson, 1989). Also, poverty is significantly correlated to certain social ills such as lack of education, higher rates of crime, and drugs (Massey & Denton, 1993; Wacquant & Wilson, 1989).

Even though the Federal Fair Housing Acts prohibits discrimination in the private housing market, a recent study done by Logan (2011) focused on the isolation and inequality of some races and ethnicities within metropolitan areas in the United States. The author found that the income of black households was lower than white household by 60% in all metropolitan regions. Between 2005 and 2009, the median income for whites was $61,706, while that of blacks was $34,496. Conversely, the author also stated that the segregation of blacks has declined slightly since 1990, and blacks have become less

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isolated—dropping from 47.1% in 1990 to 40.7% in 2009. The study also found that many blacks preferred to live in neighborhoods where most residents are black, even if this meant that they lived in low-quality neighborhoods due to their lower income and color (Logan, 2011)

d) Theories about changes in socioeconomic attributes due to other factors

Buchanan (2008) argued that higher employment density increases firms' productivity, and by extension, this improved productivity is reflected in higher earnings. The positive relationship between salaries and employment density is more intensive within higher employment density, while it may be lower in reduced employment density areas (Buchanan, 2008). In addition, college educated residents are expected to find greater employment opportunities compared to less-educated residents. As a result, residents with higher levels of education are expected to gain more income, while residents with lower levels of education are likely to work in low-paying jobs, and sometimes are even unemployed (Danziger et al., 1999). According to Mills and Price (1984), poorly educated central city residents induced the suburbanization of population and employment; in other words, highly educated residents did not prefer to live near poorly educated residents. As a result, they looked for better housing locations and higher-quality public schools for their children. Consequently, they moved to the suburbs. Businesses followed these high-class residents to the suburbs. However, low-skilled workers did not follow these jobs, resulting in residential segregation with decreased employment opportunities for low-class residents. This does not support the idea of the spatial mismatch hypothesis, where low-skilled and high-skilled workers are interrelated to each other and require socio-geographic proximity to each other (Howell-Moroney, 2005; Li et al.,2013). Howell-Moroney (2005) reported that the isolation of lower class residents in poor neighborhoods was due less educational attainment and employment opportunities, which likely led to higher poverty rates. However, in a few situations, higher employment demand raised wages, particularly for poorly educated central-city residents—and more specifically, for blacks (Dworak-Fisher, 2004; Weinberg, 2004).

2.3.2.2 Empirical studies about changes in income, race, and ethnic characteristics due to proximity to rail stations

Despite the strong connection between rail transit systems and socioeconomic attributes of residents of the neighborhood surrounding rail stations, only a few studies have looked at issues of income, race, and ethnicity of residents (Kahn, 2007; Lin, 2002; Pollack et al., 2010). This means that these factors have not received considerable attention in the academic literature compared to studies about the impact of rail transit systems on property value. The few existing studies find varying results as to the association of rail transit systems to income, race, and ethnic groups' distribution.

Investment in rail transit systems can change closer neighborhoods over time in ways that may either benefit or harm people living in those areas. The major patterns of neighborhood change are the decline in the racial and economic diversity of neighborhoods due to gentrification and displacement resulting from introducing rail transit systems (Pollack et al., 2010). Pollack et al. (2010) argued that rail transit systems usually are a catalyst for neighborhood renewal and gentrification. Therefore, the authors examined the changes of socioeconomic and demographic characteristics of a different set of neighborhoods within a one-half mile buffer from 42 different type of rail stations within 12 metropolitan areas. The study compared demographic changes in transit-rich neighborhoods (TRNs) and their respective metropolitan area in 1990 and 2000. This study analyzed results by transit type to measure the effect of each mode on the surrounding neighborhoods. The findings indicated that 64% or 27 TRNs grew in total population between 1990 and 2000, greater than in metropolitan areas. Also, half of the TRNs experienced a dramatic increase in white households compared to the rest of the metro areas, while the other half either lost some white households or increased more slowly than the rate of increase in the metro area. Compared to metropolitan area, 62% of TRNs experienced growth in median household income due to the increase in land value. The growth in income varied based on the type of rail transit. For instance, the increase in income next to light rail stations was 77%, in heavy rail stations, it was 18%, and commuter rail stations grew by 2% compared to the whole neighborhoods within the metropolitan area.

One of the most widely cited examples is the study of Kahn (2007) that examined 7,590 census tracts within 14 cities where rail transit systems expanded or were newly built. The study used both the regression model and comparison between transit area and the whole metro area between 1970 and 2000. The study found that neighborhoods around walk-and-ride stations experienced greater gentrification than ride-and-park stations, which in turn impacted socioeconomic attributes of the affected areas. For example, in 1970, only 8.2% of adults in the Davis Square area in Boston were college graduates compared to 14.7% of the entire Boston metro area. However, in 1984, a new rail station opened in that area, and by 2000, 50% of the adults residing in this area were college graduated compared to 39% of the metro area. Also, Kahn (2007) concluded that walk-and-ride stations affected land value positively and attracted upper-income households who were also college graduates. On the other hand, rail stations having park-and-ride facilities often affected housing values negatively and attracted lower educated and low-income residents to the area due to negative externalities associated with parking lots. In addition, Dawkins and Moeckel (2014) and Lin (2002) found that the presence of rail transit systems resulted in a massive gentrification in the city center and neighborhoods near rail stations. Both studies concluded that gentrification led to an increase in land value, changed racial and ethnic groups, and caused a conversion from multi-family housing to single-family housing. For example, higher land value due to improved accessibility and gentrification in Washington D.C. (Dawkins & Moeckel, 2014) and in Northwest Chicago (Lin, 2002) displaced low-income households from their old neighborhoods, and attracted wealthier ones to the areas near rail stations.

Baum-Snow and Kahn (2000) looked at the impact of expanded rail transit systems in five cities on socioeconomic factors of the residents. This study investigated census tracts around the new rail stations between 1980 and 1990, and used multivariate regression models to measure their impact. The results showed that the majority of residents living in proximity to new rail stations were whites, older, homeowners, and college graduates; these results can be attributed to the expansions of transit to the suburbs and from farther away from the downtown. However, Renne and Wells (2003) investigated the demographic information of people who lived in seven municipalities designated as transit villages in New

Jersey. The study revealed that most of the residents in these transit villages were young, single, and low-income households with more racial and ethnic diversity.

A survey conducted by Dill (2008) was mailed to 918 households who lived within one-half mile from the Westside light rail MAX stations in Portland; 323 of the surveys were completed and showed that the demographics of participating households were different still. Most of the households were childless, and the average family size was 1.3. Most households were high-income, as no affordable housing units were found next to rail stations, and all homes were in the higher end of the housing market. Also, in Portland, McKenzie (2013) investigated the differences in race, ethnicity, and poverty level in some block groups where residents relied heavily on rail transit. The study used a regression model and a before-and-after approach to find the differences in socioeconomic characteristics between 2000 and 2009. The comparison results showed that black residents in rail station areas declined from 27.9% in 2000 to 21.1% in 2009, and that they were concentrated in high-density neighborhoods. Also, the percent of poor residents slightly decreased from 28.7% in 2000 to 27.5% in 2009, but Latinos increased from 27.5% in 2000 to 29.4%. The results of the regression model showed that blacks, Latinos, and residents below the poverty level tended to live in areas with less access to rail transit, while high-income white residents settled in block groups in proximity to rail transit.

Another published article explained the socioeconomic attributes of 5,304 station-area residents in California (Lund, Cervero & Wilson, 2004). The findings showed that 62% of the residents were young, ranging between 18 to 35 years old, 83% were childless households, and 70% of employees worked in office and professional occupations. Many of the residents were from different ethnic minorities and were nonwhites. Also, Cervero (1994b) found almost similar results. He investigated residents who lived in 28 large housing projects in rail-based areas within California. He found that most residents were relatively young working professionals, who were single, empty nesters, and often owned cars.

Renne (2005) compared some socioeconomic factors of TODs and their regions in the period between 1970 and 2000 in many metropolitan areas. Renne (2005) concluded that there were no major differences in the number of nonwhite and foreign-born residents between TODs and the Metropolitan Statistical Areas (MSA). For example, the study showed inconsistent trends; in San Francisco and Los

Angeles, Blacks within TODs were greater than the region by 10%, while in Miami, blacks were lower by 8% than the MSA. In addition, the ethnic minorities within TODs were more than 10% in Atlanta, San Francisco, Washington D.C., and Los Angeles than their regions, whereas, TODs in Denver and Miami had a slightly lower ethnic make-up than MSAs. Renne (2005) found that residents living in TODs had higher income than their respective regions in Dallas, Atlanta, Miami, Chicago, and Washington D.C. since these cities built more expensive and upscale TODs. However, in San Francisco and Los Angeles, the median income in TODs was substantially lower than their regions since many blacks and other ethnic groups lived next to most TODs.

Bollinger and Ihlanfeldt (1997) estimated the impact of MARTA in Atlanta on population and employment density changed in the vicinity of MARTA stations in census tract levels measured from 1980 to 1990. They found a negative mean change in white population for all five station types (high-intensity urban nodes, mixed-use regional nodes, commuter stations, community centers, and neighborhood stations), and that the mean change of blacks was greater than zero in three stations types: 226 in high-intensity urban nodes, 187 for commuter stations, and 425 in community center stations. Arrington and Cervero (2008) looked at 17 TODs built in four major urbanized areas (Philadelphia, Portland, Washington D.C., and San Francisco) to study the changes in the characteristics of people living near stations. Using multiple regression models, results showed that most housing units located in proximity to rail stations were occupied by childless singles or couples with a wide range of ages; many of the younger residents worked in professional jobs, and most of the older residents were retired. Due to higher land value and rents in proximity to stations, most of households were affluent, especially in stations with a higher population density. In addition, persons who resided near stations owned fewer cars due to the proximity to rail stations and the smallness of housing units.

Very few studies to date have tested the changes in social and economic characteristics of residents living next to stations in the DFW area. Farrow (2001) examined the demographic and socioeconomic characteristics of residents pre- and post-construction within a one-quarter mile buffer around 20 DART stations. The study found that stations located south of downtown Dallas (the blue line) had the highest number of blacks, while rail station areas in southwest of downtown Dallas had a large

number of whites and Hispanic residents—with very few black residents. The northern station areas had the highest percentage of white residents. Regarding household income, in north stations, most residents were high-income whites, while residents in west and south stations were lower income minorities.

In addition, Mandapaka (2012) analyzed the impact of rail stations that developed as TODs in the DFW metropolitan area on residents' income, race, and ethnicity. Multilevel regression models and a comparison analysis was used to examine 59 census tracts located within a one-half network mile from rail stations. The comparison study showed that the percent of minorities in census tracts around stations were 13.5% lower than the average of whole DFW area, and the median of household income within stations was around 7% greater than the average of the DFW area. Based on regression models, the most statistically significant variables affecting residents' income positively were a lower percent of minorities, higher educated residents, better jobs, a farther distance from downtown, and more major employers. However, more minorities and proximity to highways affected household income negatively. Additionally, the study found that the farther distance from downtown and more major employer in proximity to rail stations increased the number of minorities, while more educated and working residents affected the percent of minorities negatively.

A study by Cervero et al. (2004) surveyed and examined 117 TODs in the U.S. The study concluded that most residents in the TODs were childless couples, born in the early 1960s, and empty nesters. Three of the investigated TODs were located in DFW area and were covered by DART services. The first was in the area surrounding the Mockingbird station, where most of the residents were between 35 and 45 years, worked in professional jobs, and could afford to own houses, but preferred to rent. The second TOD area was Cedars stations, where over 90% of the residents were young professional couples and empty nesters. The third area was Addison Circle, which represented a bus-based TOD; it was occupied by young professional couples with no children, empty nesters, and renters.

Several of the existing studies about changes in socioeconomic attributes due to proximity to stations have only looked at one major aspect such as changes in households' income within proximity to rail stations. These studied suggested that the increase in residential land value and rent, due to better accessibility associated with rail stations, made low-income residents move out since they could not

afford to live in neighborhoods close to rail stations (Barton & Gibbons, 2015; Dawkins & Moeckel, 2014; Kahn, 2007). A recent study by Chapple (2009) was conducted to examine neighborhood changes in the Bay Area between 1990 and 2000. The study examined 440 census tracts located within a one-half mile radius around 42 rail stations and found that around 32% or 142 census tracts became upper income in 2000, while roughly 13% or 57 census tracts became middle income, and 39% or 170 census tracts became lower income when compared to 1990. In addition, 16% or 71 census tracts become "bipolar," meaning growth of households occurred in both the lowest and highest income groups. Another study by Gossen (2005) tested the socio-demographic attributes of 15,000 households within TODs in the San Francisco Bay Area. The study showed that TOD residents had a higher income, and the most top income households lived within a quarter mile from rail stations, while the highest concentration of low-income residents was between a one-half and one-mile radius from stations.

In New York City, Barton and Gibbons (2015) tested whether the increase in land value was due to better accessibility generated by public transit (subways and buses), and whether this contributed to the displacement of low-income households between 2000 and 2010. The cross-sectional analysis showed that neighborhoods in proximity to stations had significantly higher-income households. However, the results of regression models indicated that proximity to bus or subway stations was not directly associated with changes in household income over time, but that some larger forces affected it. Changes in high-income areas were driven by other forces, such as more college-educated residents, proximity to the CBD, being adjacent to other high-income neighborhoods, and proximity to subway stations. Changes in low-income neighborhoods were generated by higher numbers of renters, population density, and the number of blacks and other minorities.

In Baltimore City, Nembhard (2009) investigated the changes in households' incomes living within half a mile from the metro and light rail stations in 1990, 2000, and 2008. The author compared household incomes within the affected area with the median income of the city with different types of public transit modes. In 1990 and 2000, the average of household income differed based on the transit mode. For instance, in 1990, households in LRT Exclusive areas had a higher income than the median of the city as a whole; the average in LRT areas was around $33,466, while the average income for the

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whole Baltimore city was $31,246. In addition, in 2000, households in LRT Exclusive areas had an average of $51,175, the highest average household income in whole the city, while households next to Metro and Metro Exclusive stations had an income of around $37,000, lower than the average of the city, which is around $42,000. Conversely, in 2008, the average household income near the metro stations was $45,000, then, followed by the average next to light rail stations with almost $43,000, and even lower was an average income in proximity to bus stops, which was $34,000. In the Nembhard study, there was not a distinctive pattern for changes in household income next to rail stations. The lowest income was for people who lived in the area surrounding the Metro, while the highest income was next to light rail transit stations in 1990 and 2000.

Another study was done by Beaton (2006) to investigate the impact of commuter rail stations in Boston on changes in land use and population density in the period between 1970 and 2000. The author also measured the desirability of residential properties surrounding rail stations by examining the movement of residents based on their income. The study concluded that high-income residents grew at larger rates in the areas surrounding newly opened stations than in the entire metropolitan area, but they declined faster around stations closed in the 1970s than those in the metropolitan as a whole. The probable reason behind this was the poor service in areas surrounding closed stations—as they attracted only low-income residents. Additionally, areas close to commuter rail stations had more diversity in the demographic change than the metropolitan as a whole.

Conversely, some studies found that rail transit stations attract more middle and low-income residents. Baum-Snow and Kahn (2005) examined the impact of rail transit expansion within 16 major U.S. metropolitan areas between 1970 and 2000. Regression models were used to estimate the impact of rail systems on census tracts within two kilometers around rail lines. The study found that the income of people who lived close to new rail stations was lower than the median income of their metropolitan areas and that the income gap was widened between 1970 and 2000, in all cities except Atlanta and Miami. As a result, the authors argued that rail stations may act as poverty magnets rather than a catalyst for gentrification. In addition, a follow-up study by Glaeser et al. (2008) used the same 16 major metropolitan areas and found similar results. The authors used a regression model to examine poverty levels in

census tracts within a one-mile buffer from rail lines and discovered that poverty levels increased as the distance to CBD decreased, particularly within less than ten miles from city center. In addition, census tracts located next to rail stations experienced poverty rates that were 4% points higher compared to census tracts beyond a one-mile buffer within the same metropolitan area. The desire of low-income residents to live closer to rail stations rose because of the difficulty of car-ownership and cheaper commuting costs of rail transit (Fan et al., 2012; Glaeser et al., 2008; Grimes & Young, 2010). In addition, when Brueckner and Rosenthal (2009) studied the impact of gentrification on housing cycles, specifically in older neighborhoods across multiple cities, they concluded that as distance increased from the CBD, household income increased by 0.2% for every mile. Also, the results showed that areas next to rail stations were more attractive to poor households since these residents wanted to benefit from cheaper commuting cost due to lower car ownership rates.

2.3.2.3 Summary

To conclude, higher land value in proximity to rail transit systems or gentrified neighborhoods near city centers are likely to attract more white residents than black residents because whites are usually wealthier than blacks, and whites and blacks tend to self-segregate into their own communities. However, if other minorities, such as Hispanics and Latinos, have higher incomes, jobs, and education, they may join whites in neighborhoods surrounding rail stations or in gentrified areas. Other factors can also isolate residents socially and spatially such as housing demand and supply, discriminatory practices in the real estate market, and some federal and local regulations.

The few existing studies looking at the changes in socioeconomic attributes of residents living in neighborhoods surrounding rail stations showed mixed results because of differences in study time, methods, and locations. For example, some gentrified TRNs or non-gentrified new transit-served neighborhoods attracted only upper-class residents. In addition, some rail station areas only experienced an increase in white, higher educated residents, where most of them worked in professional jobs. However, other scholars found neighborhoods surrounding rail stations acted as poverty magnets. Very few studies concluded that TRNs attracted more nonwhite residents. Some socioeconomic factors could vary by individual rail station or different modes of transit within the same rail transit system. For example,

some researchers concluded that some station areas attracted upper-income households and other stations attract lower-income households even when rail stations were located within the same metropolitan area. Also, few studies found TRNs were more racial diverse or more ethnical diverse.

Regarding methods used, most of the existing work compared TRNs and their metropolitan area or compared between station areas within different periods of time. In addition, very few studies used both comparison methods and regression models, and those that did used only a few variables to analyze the impacts of proximity to rail stations on socioeconomic factors of surrounding neighborhoods. However, many other factors could contribute to the changes of socioeconomic attributes of neighborhoods in close proximity to rail stations. Due to the unavailability of data for all factors, this study will be limited to the most common factors that can determine the significance of impacts on socioeconomic characteristics of residents as shown in Table 2-2.

Table 2-2 Major factors that affect socioeconomic characteristics of residents

Category	Factors affect socioeconomic characteristics of residents
Transportation accessibility	Distance to closest rail station
	Distance to nearest highway access ramp
Housing market	housing land value
	housing rent
Socioeconomic characteristics of population	Income
	Education level
	Employed residents
	Race
	Ethnicity
Location attributes	Gentrification
	Population density
	Employment density
	Neighborhood developed as TOD
	Location within the city or metropolitan area
	Distance to nearest downtown
	Distance to closest subcenter or major employment centers

2.3.3   *Theories and Empirical Studies on the Impact of Rail Transit Stations on Population Density*

In this section, the theories and literature review will be oriented to present how rail transit stations can drive development patterns including land uses and population density. In particular, the review in this section focuses on theories that have led to some changes in population density, and then, summarizes the preceding empirical studies that examined the impact of rail systems on population density for areas located in close proximity to rail stations.

The first section focuses on the theoretical background. It is categorized based on the control variables that can affect population density in close proximity to rail stations, meaning theories will be categorized according to theories about changes in population density due to proximity to transportation access, proximity to other land uses, proximity to amenities and disamenities, demographic compositions, land value, and employment density. While there are very few studies about the impact of rail stations on population density, as opposed to studies about the impact in housing value and socioeconomic characteristics of rail stations residents, the below section discusses existing studies of the impact of rail transit systems on population density. Existing studies will be organized based on findings, and whether they are positive, negative, or have no impact at all.

2.3.3.1 Theories about changes in population density

a)   *Theories about changes in population density due to transportation access*

The density gradient concept was primarily developed by Clark (1951). Clark's model explains the significance of the negative exponential equation to analyze population density, which falls within distance from the city center. Clark (1951) empirically studied a large number of European, American, and Australian cities for a number of years throughout the 19th and 20th centuries. He found that density fell off exponentially in all cities over time, becoming flatter over time due to the better income and improved transportation technologies that reduced commuting and time costs. Clark (1951) explains that the increase in population was associated with two possibilities of development: the reduction in commuting costs spread cities out, while higher commuting costs increase density at all points. In addition, under the natural evolution theory, increased commuting time and cost for jobs in the CDB, higher residential land value with proximity to the CBD, and the improved transportation technology caused developments to

move toward the suburbs, which affected population and employment densities gradients (Kolko, 2011b; Mieszkowski & Mills, 1993).

The theoretical basis for monocentric population density is derived from the work of Von Thünen that was subsequently developed by many other scholars, as mentioned earlier. Based on bid rent theory, the city center is valuable for some land uses because it is traditionally the most accessible location for a large population. Consequently, land prices are higher in proximity to the CBD. The farther the distance from the CBD, the cheaper the land. This is why city downtown areas are very densely populated, while suburbs and rural areas are more sparsely populated, with detached houses and low-density (Bluestone et al., 2008).

The bid rent model can also be applied to new subcenters in the suburbs because these subcenters often function in a similar way to the traditional center of the city (Luo & Wei, 2005; McMillen, 2004). The extension of the monocentric model is the polycentric model, which assumes that population and employment densities value transportation access, so population and employment densities decline as the distance increases from those subcenters. This means proximity to either the main center of a city or subcenters can increase or decrease population and employment densities (Giuliano & Small 1999).

Also, the bid rent model can be applied to rail transit stations since stations may play the role of the center of the city (Dawkins & Moeckel, 2014; Nembhard, 2009); the higher land value next to stations causes changes in development patterns and growth in population density (unless there are zoning or other restrictions). Weinberger (2001b) pointed out that higher land prices in proximity to rail stations led to more densely developed areas since landowners want to offset the higher land value. Also, housing demand increases since many people wish to benefit from the reduction in commuting costs. Additionally, Fujita (1989) affirmed that traditional urban economic theories have indicated that the improvement of transportation accessibility or connectivity generated by rail transit systems raises property value and induces compact development next to rail stations. However, rail transit systems can generate negative externalities that can negatively affect property value and population density (Bowes & Ihlanfeldt, 2001; Hess & Almeida, 2007; Weinberger, 2001b).

Users of highways may benefit from increased accessibility that is associated with a reduction in commuting cost and time as well as reductions in losses and injuries from accidents; also, non-users like individuals and firms may benefit from highways in indirect ways (Carey & Semmens, 2003). Gamble and Davinroy (1978) recognized that freeways made land that was previously far away from the city center more suitable for residential development by increasing its accessibility, converting it to a closer proximity to some shopping centers, workplaces, and other activities. As a result, improved levels of housing availability may attract more residents to these newly developed area, and thereby, produce a greater density in the areas nearby highways and increase demand for local community services such as schools, fire departments, and utility services (Carey & Semmens, 2003). However, negative externalities associated with highway development may decrease population density if, for example, residential properties are immediately adjacent to the highway (Langley, 1981). In short, location advantages and disadvantages can either foster population density or decrease it (Voss & Chi, 2006).

b) *Theories about changes in population density due to different land uses and amenities*

Not only distance to the CBD or proximity to rail stations can be considered as factors affecting population density functions, but some authors have also found that other factors can be added to explain population density functions. According to Mills and Price (1984), there is interdependence between employment and population suburbanization. Steinnes and Fisher (1974) reported that industrial uses in the central city were one of the major forces behind residential suburbanization because of negative externalities that affected residents adversely, while retail employment density had a positive and significant relationship with population density. Also, Levernier and Cushing (1994) showed that the most significant determinants of population density were housing prices and neighborhood quality. For example, population density was affected negatively by the manufacturing sector and positively by the service and retail trade sectors (Levernier & Cushing, 1994). Some other land uses can affect residential land value and density negatively such as landfills, waste sites, nuclear power plants, hazardous manufacturing facilities, and industrial facilities (Cheshire & Sheppard, 1995). Regarding different land uses next to rail stations, Schuetz (2014) argued that denser neighborhoods surrounding rail stations were positively associated with commercial land uses since these neighborhoods can provide more

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consumers. The presence or absence of vacant lots may also have a significant impact on population density; the presence of vacant land was negatively correlated to population density, whereas a decreased portion of vacant land meant moderate or high population density (Mills & Tan, 1980; Smith, 1997). In short, commercial, service, and retail land uses may generate higher population density due to the high demand between residents and firms selling consumption goods to consumers. Reduced vacant land may increase the number of residents in these areas, but landfills, waste sites, and industrial uses are adversely associated with population density.

Most of the transit stations developed as TODs represent a form of mixed use development with moderate to high density, and they are designed to encourage people to bike and walk in the area adjacent to rail stations (NCTCOG, 2011). Also, as the number of amenities increases in a neighborhood, the demand for lands increases, which results in a higher residential value (Cheshire & Sheppard, 1995; Song & Knaap, 2004), and therefore causes changes in development patterns and increases population density (Bluestone et al., 2008). However, high-income residents are willing to pay a premium for access to amenities and prefer single-family housing with large lot sizes. As a result, the density is lower in the neighborhoods with better amenities (Ottensmann, 1977). Alperovich (1980) added that higher-income residents increased the demand for high quality and low-density areas that have better amenities.

c) Theories about changes in population density due to land value and employment density

Based on bid rent theory, property with proximity to the center of the city has a higher price than more distant properties (Bluestone et al., 2008). Landowners are willing to offset the higher price of land in the CBD and maximize the returns on the property (Huang, 1996), so some land uses will be converted to other higher density uses, such as multifamily housing units, retail, and offices. Hence, the CBD is expected to grow and develop (Huang, 1996).

Since the 1980s, the monocentric model gradually developed into the polycentric model due to decentralization (Shukla & Waddell, 1991; Small & Song, 1994). As previously mentioned, the polycentric model assumes the importance of transportation access in maintaining population and employment densities value, and thus population and employment densities decline with distance increases from these subcenters (Small & Song, 1994). Also, several scholars assume that the shape of employment

density is similar to the shape of population density, but somewhat more centralized (Small & Song, 1994). Furthermore, the natural evolution theory assumed that increased commuting time and cost to jobs in the CDB, higher residential land value with proximity to the CBD, and improved transportation technology caused development to move toward the suburbs, which affected population and employment density gradients (Kolko, 2011b; Mieszkowski & Mills, 1993).

Therefore, both bid rent theory and natural evolution theory can be applied to rail transit stations since stations can be considered an extension of the city center (Dawkins & Moeckel, 2014; Nembhard, 2009). As a result, proximity to rail transit stations may play an instrumental role in increasing population and employment density in the proximate areas. Nevertheless, the lack of job opportunities or presence low-paying jobs can be considered as one of the important factors of net out-migrations and consequent depopulation; in other words, lower unemployment rates are associated with an increase in population density (Millward, 2005).

d) Theories about changes in population density due to socioeconomic attributes of residents

Changes in some demographic compositions over time may affect the shape of the population density gradient. Smith (1997) noted that during the 1960s and 1970s, several researchers found changes in the population density gradient because of certain historical, spatial, and socioeconomic factors. For instance, Ottensmann (1977) affirmed that change in income played a major role in land prices and population density. Higher-income households preferred single-family housing with a large lot size, resulting in lower population density. In addition, Mills (1972) used a two-point method and found that the major determinants of historical leveling out of the population density function were population size and income. Alperovich (1980) added that as income increased, the demand increased for high quality and low-density neighborhood housing. He also stated that as the households' incomes increased, they would shift their bids for housing land away from the city center, where housing and neighborhood quality were low and density was higher, to areas farther away where housing and neighborhood quality were higher and density was low. This shift resulted in changes in population density in proximity to the CBD and in suburbs—since the increase in income caused a flattening in density gradients.

Galster (1982) reported that race was strongly correlated to income in various ways. Whites and blacks typically self-segregate into mono-ethnic communities, meaning that members of each race prefer to live with members of their own race (Galster, 1982; Ihlanfeldt & Scafidi, 2002), resulting in more homogeneous demographics within neighborhoods (Howell-Moroney, 2005; Tiebout, 1956). The "flight from blight" hypothesis can also explain the main factors that have led to suburbanization (Anas et al., 1998). The first factor is the deteriorating quality of housing in city centers resulting from style or technological obsolescence and the reduction in maintenance of old buildings. The second is racial preferences and the desire of some poor black residents to live in the city center. The third reason is negative externalities associated with many poor neighborhoods. The fourth is related to the quality of public goods and services such as schools, shopping malls, etc. These factors imply that poor and black residents live in the areas near city centers and that high-income residents are pulled out to the suburbs (Anas et al., 1998).

Muth (1969) pointed out that improved transportation technology, a higher percentage of blacks, and manufacturing employment in the city center could affect population density. Therefore, the lower neighborhood quality due to a presence of black residents, substandard housing, and manufacturing employment was associated positively with a population density gradient, while the increased size of the population and more prevalent car ownership had a negative relationship with population density gradient. Additionally, Winsborough (1965) found that changes in transportation technology led to more ownership of cars, which resulted in lower density in the city center and greater suburbanization. In addition, racial and ethnic mixture increased crime rates. This caused higher-income and highly educated households to move to the suburbs to find better-educated neighbors and higher-quality schools for their children (Mills & Price, 1984). As poverty is usually associated with non-white and low ethnic class people, it leads these groups to live in high population density where neighborhood quality is bad and buildings are old (Galle et al., 1972).

As a result, there is a tendency for homogeneous communities to become established within specific areas. Neighborhoods in the suburbs will have lower-density neighborhoods dominated by higher-income and more educated whites who live in detached houses with large lot sizes. Poor and less-

educated black residents will be concentered in old neighborhoods in the city center, even though these old centers are densely populated, lack public services, educational institutions, and social interactive effects (Riddick, 2014).

2.3.3.2 Empirical studies on the impact of rail transit stations on population density

The literature is rich regarding the impact of rail transit stations on land value, but there is limited work on the impact of rail transit stations on the population density of the surrounding neighborhoods. The results of existing work are mixed. Some found positive impacts on population density and others did not. The patterns of density are one of the most significant structural characteristics of any city or metropolitan area. Urban density examines the spatial arrangement of population and development patterns; it also is considered a measure of concentration that can explain urban structure (Clark, 1951).

Since the resurgence of rail transit systems, many planners have begun to think about guiding development toward rail transit areas which, in turn, would restrict metropolitan areas from more sprawl and car dependency and induce higher density development (Huang, 1996). Therefore, some cities adopted higher development densities and substantial development around stations; others saw transit stations as nodes for offices and retail activities; while other cities applied transit-oriented development in areas surrounding stations (Huang, 1996). Furthermore, higher population density may influence significant changes in land uses toward more mixed-use developments and compact growth (Handy, 2005). It also can be considered socially beneficial since it increases rail transit patronage, generates higher tax revenues, and increases employment opportunities especially for transit-dependent workers (Bollinger & Ihlanfeldt, 1997). However, metropolitan growth in many cases does not follow the transit systems, and the impact of rail stations on development patterns is not as direct as many planners expected (Huang, 1996). Also, higher population densities that are restricted by zoning ordinances may prevent residents from moving to live in closer proximity to rail stations (Cervero, 2007).

A good number of existing studies confirmed that rail transit systems can increase population density of the neighborhoods surrounding rail stations in some cities such as Boston, Montreal, Philadelphia, Toronto, and Washington, D.C. One of the earliest studies examining rail systems was done by Knight and Trygg (1977). This study compared the impact of different rail transit investments on land

uses. Their survey showed that the Lindenwold rail transit system in Philadelphia stimulated the development of many apartment buildings in neighborhoods surrounding rail stations, which increased the population next to stations. In addition, a later study by Badoe and Miller (2000) examined the same transit system and asserted that not only did neighborhoods in close proximity to stations experience a growth rate of new development, but all parts of Philadelphia experienced an either equal or greater population density during the same period.

The majority of studies found a strong positive relationship between rail transit stations and population density, but that higher population density would not necessarily result only from the proximity to rail stations or the increase in transit use (Newman & Kenworthy, 1989; Kenworthy & Laube, 1999). Shen (2013) thoroughly studied the impact of rail transit systems on population and housing density on four major metropolitan regions: Chicago, Denver, Los Angeles, and Washington, D.C. The study analyzed data between 1990 and 2010, and utilized regression models to examine the major changes in density within a one-half mile radius from stations. The results showed that most of the station areas associated with compact development, moderate-income residents, and housing uses were more likely to have higher population and housing densities. Another major finding was that heavy rail transit can promote more population and housing densities than light rail stations; also, the expansion of existing rail transit systems would have more population and housing densities than new rail transit systems. Another study, by Arrington and Cervero (2008), examined the changes of residential density around 17 rail stations in four of the major urbanized areas. This study found that residential density in areas near stations within the 17 stations increased by between 20% and 330% based on the type of buildings found respectively within each TOD.

Several studies also suggested that higher land value in proximity to rail stations can promote population density, while the presence of ride-and-park facilities significantly reduces population density. Fujita (1989) affirmed that the improvement of transportation accessibility and connectivity resulting from a rail transit system increased property value and promoted more compact development surrounding rail stations. Also, Weinberger (2001b) argued that higher land prices in proximity to rail stations generated

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more densely developed areas because many people wished to benefit from the reduction in commuting costs, but denser areas only attracted high-income individuals due to higher land value.

In one study, it was found that Boston also experienced dramatic growth in population density around rail stations. Beaton (2006) investigated changes in land use and population density around Boston commuter rail stations between 1970 and 2000. The author used ArcGIS and remote sensing to find changes within census tract levels. The study found that the changes in land uses next to closed stations, that lost rail service, were greater than neighborhoods next to newly opened stations, and that the new stations were denser than the closed ones. In addition, a larger number of multi-family housing units were built near new stations than both the stations that lost service and the entire region. In addition, Beaton (2006) looked at population density to see whether more people moved into the area surrounding commuter rail stations. The author suggested that the rate of vacant land declined sharply between 1970 and 2000. Most of the development was in the form of condominiums, meaning a major increase in population density. The study concluded that the increased desire to live in neighborhoods surrounding stations led to smaller housing units, which also generated higher density. Similarly, McDonald and McMillen (2000) examined suburban development in different land use types between 1990 and 1996. They used OLS to test the changes in around 15,000 quarter sections (one-quarter square mile) within Chicago. The results showed that housing units per quarter section were negatively correlated to distance to the airport, but strongly associated positively to the vicinity of rail transit stations and employment centers.

Hurst and West (2014) used the before and after method in their study of the Hiawatha light rail in Minneapolis starting from when it opened to investigate the impact of METRO Blue stations on land uses. They tracked data during the construction (2000-2005) and after the system began operating (2005-2010) within a half-mile buffer from stations. The study found that the changes were pronounced in the number of multi-family housing and amount of vacant land during the construction. Multi-family housing increased by 11.3% in neighborhoods surrounding stations, while it only increased 1.9% in the city. In addition, vacant land declined by 5.7% in the transit area and increased in the rest of Minneapolis by 3.6% during the construction period. After opening the rail system, changes in land uses accelerated. For example,

multi-family housing near stations increased by 16.6%, but in non-affected areas, there was almost no change. The authors noted that higher land prices led landowners to build more multi-family units. Moreover, in the same study, authors used multiple regression models to examine the impact of stations before, during, and after the operation on the block groups within a one-half mile radius of stations and compared it to the impact on the city. The researchers have found the need to include many other independent variables because they may affect population density greater than the proximity to rail stations. The findings of regression were in contrast with the findings of the before and after method. This showed that land use changes were significantly greater within neighborhoods surrounding stations than in the rest of the city.

Some studies found that more emphasis is being placed on clustering more multi-family housing in neighborhoods around rail stations. Bernick (1993) and Bernick and Cervero (1994a) concluded that many multi-family projects were built within a one-quarter mile radius around rail stations in the period between 1988 to 1993. For instance, 11 multi-family projects with more than 4,500 units were built in proximity to BART stations (Bernick, 1993), and on the nationwide level, approximately 12,000 multi-family units were built around rail stations within ten major metropolitan areas between 1988 and 1993 (Bernick & Cervero, 1994). In addition, 20 years after the opening of BART, Cervero (1995) conducted a study to examine the impact of BART on population changes between 1970 and 1990. The study used a matched pairs method to compare population change in BART-served and non-BART-served parts of the Bay Area. Between 1970 and 1990, over 85% of census tracts surrounding BART stations had over seven persons per acre, which can be considered the highest population density within the three counties that were served by BART. However, the growth of population was two-thirds faster in an area not served by BART than the area near BART stations. In other words, the percent change in population growth in BART areas was 17.1%, while it was 35.2% in non-BART areas. The authors found that fastest growth happened in the suburban and exurban areas that were not served by rail stations. This can be attributed to the massive movement of people toward the suburbs in that era.

On the other hand, some neighborhoods nearby rail stations experienced little or even negative change in population density. According to Cervero (1995), most of the studies examined the impacts of

BART during the mid-1970s and found a fairly moderate impact on residential land uses and urban development in the Bay Area; no induced growth was shown, but some redistributed growth took place. In another study, Landis et al. (1995) examined the impact of nine BART stations and four San Diego Trolley stations on land use changes within one-half mile radius between 1965 and 1990. Before-and-after and logit model methods were used several different times and included a set of explanatory variables. The results showed that around 44% of residential uses converted to commercial uses and 37% converted to parking lots for the rail system during the period of study. This led to a major increase in commercial use and a major decline in residential use within rail stations. Also, one of the most cited studies found almost similar results. Cervero and Landis (1997) measured the impact of BART stations on the development patterns within a one-half mile buffer around 25 stations and a one-quarter mile from downtown stations. The study concluded that areas next to San Francisco and central Oakland downtown stations experienced higher non-residential development, especially in the form of offices and retail towers, while few multi-family residential developments were built near the rest of the stations.

In addition, several studies found that many commercial uses over time tended to replace residential and industrial uses in proximity to stations (Vessali, 1996). For example, a before and after study of Washington D.C.'s Metro found that most of the areas previously assigned to be warehouses or industrial use properties were converted to mixed-use projects (Donnelly, 1981; Dunphy, 1982). In another study, the expansion of O'Hare Road transit in Chicago reduced residential constructions from 64% before the expansion to around 7% during the construction of the rail line; the major increase was in commercial developments (Chicago Area Transportation Study [CATS], 1986). In addition, a before and after study of the Red Line extension in Boston concluded that the expansion was more significantly attractive to commercial uses, less attractive for residential ones, and particularly repellent for industrial uses (Quackenbush et al., 1987).

In the study done by Farrow (2001), the author examined the trends in land use patterns within a one-quarter mile radius around 20 DART stations for the period between 1990 and 2000, which are the pre- and post-construction eras. The most significant change in land use occurred around northern stations, where many commercial and multi-family housing units existed, while many single-family

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residential housing were constructed in the southern stations. In addition, two of the southern stations located close to downtown Dallas experienced modest increases in industrial land uses. Moreover, many vacant lands were developed near all stations. Close to the northern stations, most vacant land was developed for commercial uses; whereas, in southern stations, vacant land was developed into single-family residential units, a few commercial units, and some industrial buildings. In short, this study showed that there was no major increase in population density since many areas surrounding rail stations were developed for commercial or industrial uses.

Dueker and Bianco (1998) surveyed the impact of eastside Portland Max rail on land use and residential density. The before and after method was utilized to investigate the land use impact of MAX stations. The area studied was a one-quarter mile radius from rail stations, bus stops, and major arterials. This study measured the changes in land uses. Between 1986 and 1995, results showed that 17% of multi-family projects were built next to rail stations and 71% were next to bus stops. However, gross residential density within rail stations did not change (it was consistently 3.91 units per acre of each block group), but increased next to bus stations from 3.98 in 1980 to 4.11 in 1990. Also, net residential density declined in both areas surrounding rail stations and bus stops by 1.60 and 0.22, respectively. The potential reason for lower density in close proximity to rail stations was because of the major increase in commercial uses within block groups surrounding rail stations.

Bollinger and Ihlanfeldt (1997) estimated the impact of MARTA on densification of population surrounding station areas in census tracts levels measured from 1980 to 1990. Authors used a regression approach and simultaneous models of population. The results showed that the mean change in population for the station was -274, and +2,291 in non-station census tracts. This indicated that population change is considerably greater in non-station areas than in station areas. In general, the development of MARTA system had no positive or negative impact on population density in station areas. Another study investigated the changes within a one-half mile from MARTA stations and found that census tracts around stations lost 11% of their residents, whereas employment increased by 13% (Nelson, et al. 1997).

Knight and Trygg (1977) found a positive impact of the Washington D.C. Metro on population density, but rail transit systems in Chicago did not generate any impact on population density due to higher land value and downtown neighborhoods that already had been developed with higher density. Similar evidence was found when Allen (1986) tested the impact of rapid transit in Cleveland. This study found that the rail system was not effective at all in attracting residential development—since the rail line passed through an industrial area and was isolated from the adjacent properties because it used old railroad lines that were steep embankments.

Some of the preceding studies that surveyed the changes in residential land use due to proximity to rail stations found that the effect of heavy rail systems was small, that the impact of light rail systems was smaller, and that most rail transit systems did not increase residential use in neighborhoods surrounding rail stations (Vessali, 1996; Handy, 2005). In addition, the magnitude of the impact can vary based on neighborhood and spatial contexts. For instance, investments in rail transit systems in lower density or auto-oriented cities, such as Minneapolis and Dallas, may not increase the marginal accessibility of a location enough to attract more residents and businesses to locate in proximity to rail stations (Billings, 2011; Handy, 2005). In addition, the study of Knight and Trygg (1977) could not find clear evidence that rail transit systems increased the densification or changes in land uses because several cities were already served by convenient automobile and rail transit, so they did not contribute to further improvement in accessibility. Additionally, the authors asserted that four main factors contributed to the growth of population and changes in land use within stations areas: available land for development, less physical constraints, more regional development trends, and local government policies motivating more development such as high-density zoning allowances. Also, Giuliano (1995) asserted that government intervention was the major way to increase the demand for land and denser residential development in proximity to rail stations.

2.3.3.3 Summary

Based on the theoretical framework, the major factors that may affect population density in this case study are improved transportation accessibility to: the city center, economic subcenters, the closest highway, and rail transit stations. Also, other elements besides increased accessibility can affect

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population density, including proximity to different land uses. For instance, proximity to industrial land uses and landfills can reduce population density, while service and retail use increases population density. Amenities can increase land value, and therefore either increase population density, or decrease it, since higher-income households prefer single-family housing units with large lot size. Finally, changes in income, education, race, and ethnicity can interact either positively or negatively with population density.

In the past few decades, a few evaluation studies examined the changes of population density in neighborhoods surrounding rail transit stations. The results of these studies were mixed and inconsistent; results were different from one study to another in presence, magnitude, and range of the impact on population density changes. In some of them, transit areas experienced higher population density. Other cases found that neighborhoods surrounding rail stations experienced a decline in population density after operating rail transit system and were instead more attractive to commercial uses. In addition, some of the existing work concluded that proximity to rail stations did not affect population density in any way. Furthermore, some of the prior work found an increase in population density with some stations and a decrease with others within the same transit system.

Regarding the method of these preceding studies, most of them used a before and after method to measure the changes caused by establishing rail transit projects; however, few studies used both pre- and post- method or regression methods, and very few studies used the matched pair method. Many authors concluded that not only could proximity to rail transit stations affect population density in neighborhoods near stations, but many other complementary factors could also play a vital role in affecting population densification in transit area (Hurst & West, 2014; Giuliano & Agarwal, 2010; Landis et al., 1995; Vessali, 1996). Due to the unavailability of data for all factors, this study will be limited to the most common factors that were used in most of the existing studies and could determine the significance of impacts on population density characteristics as shown in Table 2-3.

Table 2-3 Major factors that affect population density next to rail stations

Category	Factors affect population density
	Factors affect population density
Transportation accessibility	Distance to closest rail station
	Distance to nearest highway access ramp
Housing market	Housing land value
Land uses	Residential uses
	Commercial
	Industrial uses
	Rate of vacant land
Socioeconomic characteristics of population	Income
	Education level
	Race
Location attributes	Employment density
	Neighborhood developed as TOD
	Distance to nearest downtown
	Distance to closest subcenter or major employment centers

Chapter 3

Methods and Techniques

This chapter explains the study area and methods that used to carry out the task of finding

evidence for how rail transit stations might affect the economics, socioeconomic attributes, and spatial

factors of neighborhoods surrounding rail stations in the Dallas-Fort Worth (DFW) metropolitan Area. The

methodology and variables of this study are taken and analyzed from several of the existing studies and

theories mentioned in Chapter 2, Review of the Literature. This chapter begins with some details about

the data sources that will be utilized for this research study. The second section describes the study area,

proximity measures, techniques, and rules to determine the block groups that will be included in the study

area. This is followed by a section explaining different quantitative measurements, dependent and

independent variables, and the techniques that will be utilized to address the three research questions.

Research questions and the hypothesis of this study will be discussed in the final section.

3.1 Data Sources

This study covers the period between 2000 and 2014. This period can be considered a relatively

long period of time—which is ideal because over longer periods of time, the evaluation always has a

strong impact or the actual impact can be measured, whereas the short run effect is mostly zero

(Weinstein & Clower, 1999). In addition, this study uses a small-scale geographic census unit (i.e. a block

group) to obtain more accurate results than larger geographic census units; however, getting all needed

data for block groups is very difficult and much data is unavailable. Three primary data sources will be

used for this study, including data from the U.S. Census, North Central Texas Council of Governments

(NCTCOG) Regional Data Center, and public agencies providing rail transit systems in the DFW area

(DART, DCTA, and the TRE).

3.1.1   U.S. Census Data

Most of the data for the block group level related to population, race, ethnicity, education,

employment, housing land value and rent can only be found in the 10-year U.S. Census and the 5-year

American Community Survey (ACS). For this study, the 2000 Census and the ACS 2010-2014 are used

to compare the changes in the selected block groups next to rail transit stations in the DFW area over a

fourteen-year period in order to help to answer the research questions. Although it is not optimal to compare the 2000 Census to ACS 2010-2014, the data for block group level is only available from those two data sources. However, there is precedent for this type of comparison. Many studies have compared both Census and ACS data such as Bhattacharjee (2013), Mandapaka (2012), McKenzie (2013), Shen (2013), and Schuetz (2014). With respect to the total number of jobs for each census block group, jobs data from 2002 to 2014 can only be found in LEHD Origin-Destination Employment Statistics (LODES). It must also be taken into consideration that changes in geographic census units' boundaries between 2000 and 2010 will introduce room for error into some of the calculations, especially when modifying boundaries from one year to another (Beaton, 2006).

3.1.2 *North Central Texas Council of Governments (NCTCOG) Regional Data Center*

The NCTCOG Regional Data Center provides objective data and analysis on the development of the NCTCOG region related to urban planning and economic activities. Most of the data taken from the NCTCOG is mainly related to the ArcGIS database, such as highway layers, schools, shopping mall, major employers, rail transit systems, and stations.

3.1.3 *Other Data Sources*

Other data can also be derived from public agencies providing rail transit systems in the DFW area (DART, DCTA, and the TRE), which are discussed below in more detail. Also, other data sources will be used as needed, such as Case-Shiller Home Price and Consumer Price Index.

3.2 Study Area and Unit of Analysis

Rail passenger transportation in the Dallas-Fort Worth metropolitan Area is provided by three regional transit agencies—including Dallas Area Rapid Transit (DART), Denton County Transportation Authority (DCTA) and Trinity Railway Express (TRE)—and serves four urban counties (Collin, Dallas, Denton, and Tarrant) as shown in Figure 3-1 (NCTCOG, 2013a). In these four counties, 20 cities are served by 74 rail stations along 146 miles of light and commuter rail as shown in Figure 3-2. DART is the largest agency that provides rail services. It covers 13 member cities along 90 miles of light rail transit (59 rail stations). TRE links downtown Fort Worth and downtown Dallas with roughly 35 miles of commuter

rail service (10 stations) in four cities; DCTA provides 21 miles of commuter rail that serves three cities (6 stations) (NCTCOG, 2015). As mentioned earlier, one motivating factor for doing this study is that the DFW area has the longest rail transit system, but no major study has examined its impact. Also, cities served by transit in the DFW metropolitan area are low-density and automobile-oriented cities, and therefore these systems do not improve transit accessibility or attract more residents and commercial activities next to rail stations.
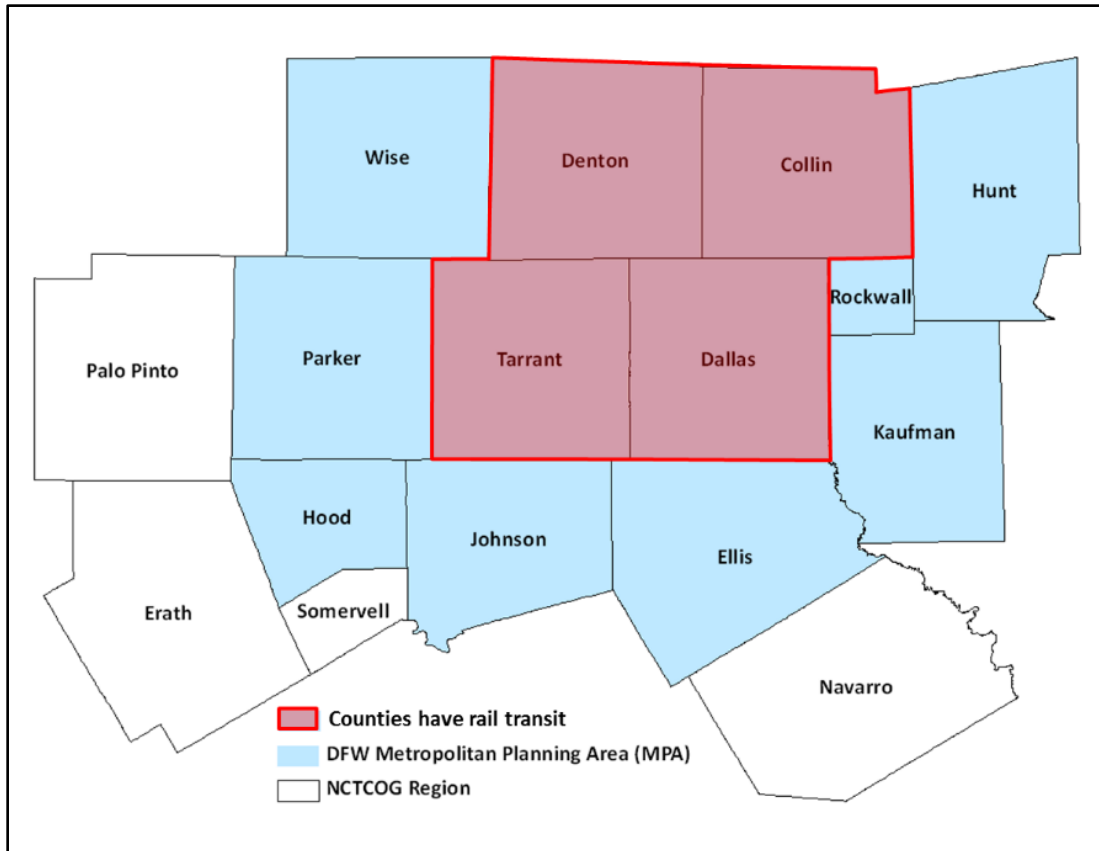
Figure 3-1 NCTCOG Region
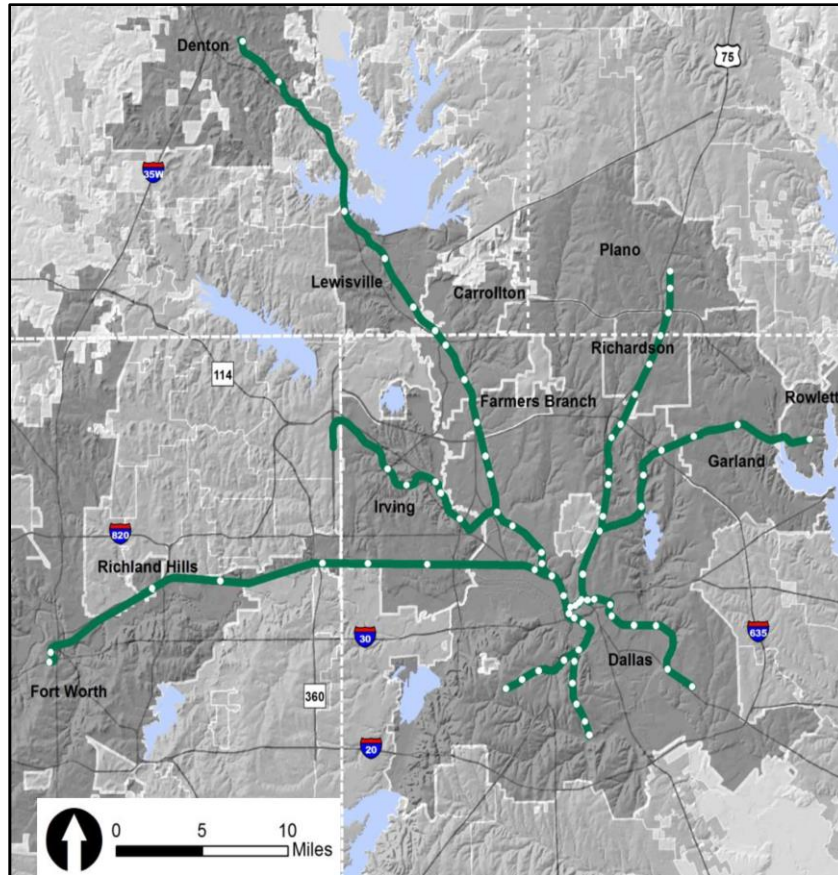
Figure 3-2 Dallas-Fort Worth area rail transit systems

Source: http://www.nctcog.org/trans/sustdev/tod/WorkGroup.asp

Many relevant studies about the impact of urban rail transit stations have been reviewed both to see what proximity measures are used and to identify the spatial analysis cases and techniques used to determine the inclusion or exclusion of the cases being studied. In the existing literature related to the impact of rail transit systems on surrounding areas, different proximity measurements have been utilized—since no solid theory has been agreed on that can guide scholars to determine the appropriate affected area (Shen, 2013). The impact of rail stations usually falls within a limited distance, and this distance is mainly determined by the feasible distance for walking to and from the rail stations (Diaz, 1999; Stecker, 2005). The shortest and dominant proximity measure found in the literature is one-quarter mile from stations, which equals an approximately five-minute walk on foot (Bernick & Cervero, 1997; Untermann, 1984). Beyond this distance, the impact decreases because of time costs and inconvenience

that inhibit the ridership of mass transit (UMTA, 1979). However, Golub et al. (2011) argued that, in practice, a one-quarter mile radius may not capture all impacts of rail transit since some effects may extend farther out. Accordingly, one-half mile can be the maximum distance that transit riders can walk to and from rail stations (Billings et al., 2011; O'Sullivan & Morrall, 1996). A large number of prior studies extended the buffer to one-half mile around stations (e.g. Armstrong & Rodriguez, 2006; Cervero & Landis, 1997; Hurst & West, 2014; Schuetz, 2014; Weinberger, 2001a). Other scholars challenged the traditional one-half mile standard measure and argued that transit riders were able to walk one mile or even more because people in average physical condition can walk this distance in around 15 to 17 minutes, which is a reasonable time to reach a station (Canepa, 2007; Duncan, 2008; Knaap et al. 2001; MWCOG, 2004; Vinha, 2005). Moreover, the existence of park-and-ride facilities can widen the impact of rail stations by more than half a mile (Cervero, 2001; Frank et al., 2008; Marchwinski, 1998; Vinha, 2005; Yan et al., 2012). Also, some of the existing studies found that a two-mile radius is statistically significant and can adequately capture the impact of transit stations (Kay et al., 2014; Nelson et al., 2015).

Additionally, many studies included multiple rings around stations ranging from two rings to up to five rings, and those rings are usually divided into one-quarter or one-half mile segments. For example, Cervero and Duncan (2002c) used one-quarter and one-half mile rings around rail stations in San Diego County and found both distances were statistically significant in predicting the impacts of rail stations. However, the impact diminished immediately beyond the half-mile buffer. In addition, Bowes and Ihlanfeldt (2001) found that the impact of MARTA stations in Atlanta affected residential and commercial properties up to three miles from rail stations, but the major impact occurred within the first half a mile from stations. Also, Pan (2013) found that the impact of the Houston METRORail stations on home prices extended three miles from stations. A couple of existing studies did not identify any positive or negative impact within the first ring, but found some impact in subsequent rings due to negative externalities associated with rail transit systems (Bowes & Ihlanfeldt, 2001; Landis et al., 1995; Lewis-Workman & Brod, 1997; Strand & Vågnes, 2001).

Census units (e.g. block groups, census blocks) rarely, if ever, align with the circular buffers around rail transit stations. In other words, most block groups have irregular shapes and they rarely

coincide with geographic boundaries selected for a census (Hartell, 2008; Sanchez, 1998). Therefore, the selection of census units within an identified buffer around rail stations requires some methods to determine the inclusion or exclusion of the cases being studied. Chakraborty and Armstrong (1997) stated that three common methods could be used to select potential census units within a study area; these include polygon containment, centroid containment, and buffer containment as shown in Figure 3-3. Polygon containment, also known as the touching method or boundary intersection method, is a method where all census units are either entirely enclosed within or intersect with buffer boundaries that will be included in the study area. The second method is centroid containment, which means that census units will be only included in the study area if their centroid or 50% of their area fall within the buffer zone. The third method is buffer containment, also referred to as a percent-inside method. This method reviews census units that fall within the actual shape of the circular buffer; if the unit does not fall completely within the buffer, the proportion of the census unit that is contained within the buffer will be used. So, census units that are not fully inside the buffer need to be calculated with the percentage of the area within the buffer, and then, assigned the same percentage for the study area.

Several of existing studies related to the impact of transit stations use the centroid containment method (e.g. Bollinger & Ihlanfeldt, 1997; Guerra, 2014; Miller & Nelson, 2014; Ratner, 2001; Sanchez, 1998). Ratner (2001) affirmed that centroid containment is effective in defining the exact affected area around transit stations because many far-reaching census units away from a city center are large. Moreover, these block groups can include too much area if the touching method is chosen. Also, Bowes (1999) and Bowes and Ihlanfeldt (2001) asserted that if the centroid of a census unit falls within the buffer zone, then the larger the area of the census unit will be that is inside the affected area. However, some studies used the polygon containment method (e.g. Duncan, 2007; Hart & Lownes, 2013; Kolko, 2011a; Loukaitou-Sideris et al., 2002; Nembhard, 2009; Schuetz, 2014). It can be suggested that the reason behind choosing polygon containment is that one-quarter or one-half mile buffers are usually smaller than the size of most census units, so some portions of the polygons will fall out of the buffer boundaries. On the other hand, many of the existing studies did not mention the selection methods that were used to determine the inclusion or exclusion of the cases being studied.
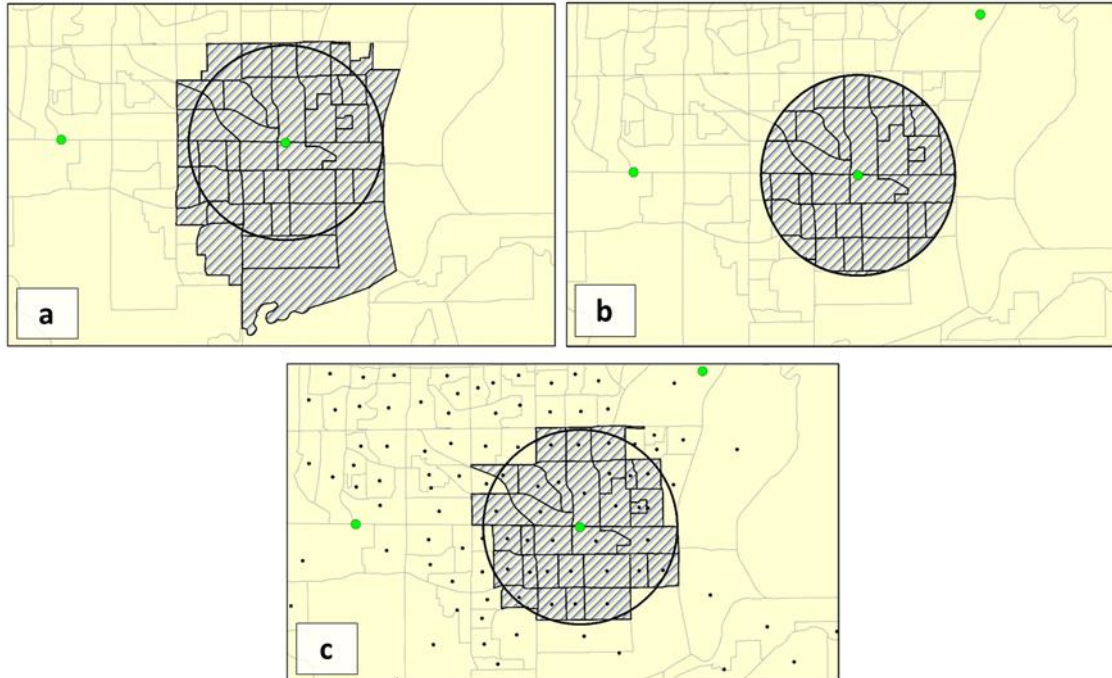
Figure 3-3 Methods for determining study area: (a) polygon containment, (b) buffer containment, and (c) centroid containment

Accessibility distance in transportation studies can be measured using ArcGIS, and there are two methods to measure the distance to rail stations: straight-line distance and network distance methods. The straight-line distance method is an air distance or perceived distance between an origin and destination, while the network distance method is the actual walking distance between an origin and destinations (Clifton & Handy, 2001). Most of the previous studies related to the impact of urban public transit systems have used the straight-line distance method, which is also called the Euclidean distance process; a few have utilized the network distance method since they believe this type of measurement makes more theoretical sense (Duncan, 2008). Hess and Almeida (2007) show that the actual walking distance between home and the closest rail station may equal the straight-line distance model, but network distance will never be shorter. Furthermore, several studies used both measurements and found that the two measurements are statistically significant, but network distance is more statistically significant (Hess & Almeida, 2007; Golub et al., 2011; Hubner, 2015).

After reviewing the existing literature related to the impact of rail stations on the proximate areas, a solid theory has not been found to guide scholars in deciding the range of proximity affected by rail transit facilities. For this study, a one mile buffer around rail stations will be used since many scholars assert that it is a reasonable walking distances for transit riders because it can take about 15 to 17 minutes to walk this distance (Duncan, 2008; Knaap et al., 2001; MWCOG, 2004; Vinha, 2005). Also, block groups outside of major downtowns are large and choosing only a half mile radius would result in very few units within the study area (Sanchez, 1998). Third, the expansion of buffer zones around rail stations can capture variations in economic, social, and spatial aspects. Fourth, the availability of park-and-ride facilities may expand the influence of rail stations since more people will drive to transit stations (Cervero, 2001; Frank et al., 2008; Marchwinski, 1998; Vinha, 2005; Yan et al., 2012). Finally, some of the existing works use a one-mile or wider radius and found it statistically significant (Duncan, 2008; Vinha, 2005).

The method that will be used to determine the selection of which block groups are included or excluded in the study area is the centroid containment method: if the centroid point of the block group or half and more of its area fall within the buffers, it will be included within the study area as shown in Figure 3-4. This method is chosen since it is more accurate than other selection methods as discussed before (Bowes, 1999; Bowes & Ihlanfeldt, 2001; Maantay & McLafferty, 2011; Ratner, 2001). As for the technique to measure the accessibility distance from transit stations, this study will use straight-line distance method (Euclidean distance model) since most of the previous studies used this method and did not find major differences from the network distance. In addition, some authors (e.g. Hess & Almeida, 2007; Golub et al., 2011; Hubner, 2015) have tested this technique and found it statistically significant. Figure 3-5 shows all block groups for the study that will be included in this analysis; in total, the study will cover 454 block groups within the one-mile radius from all rail stations along the 150 miles.
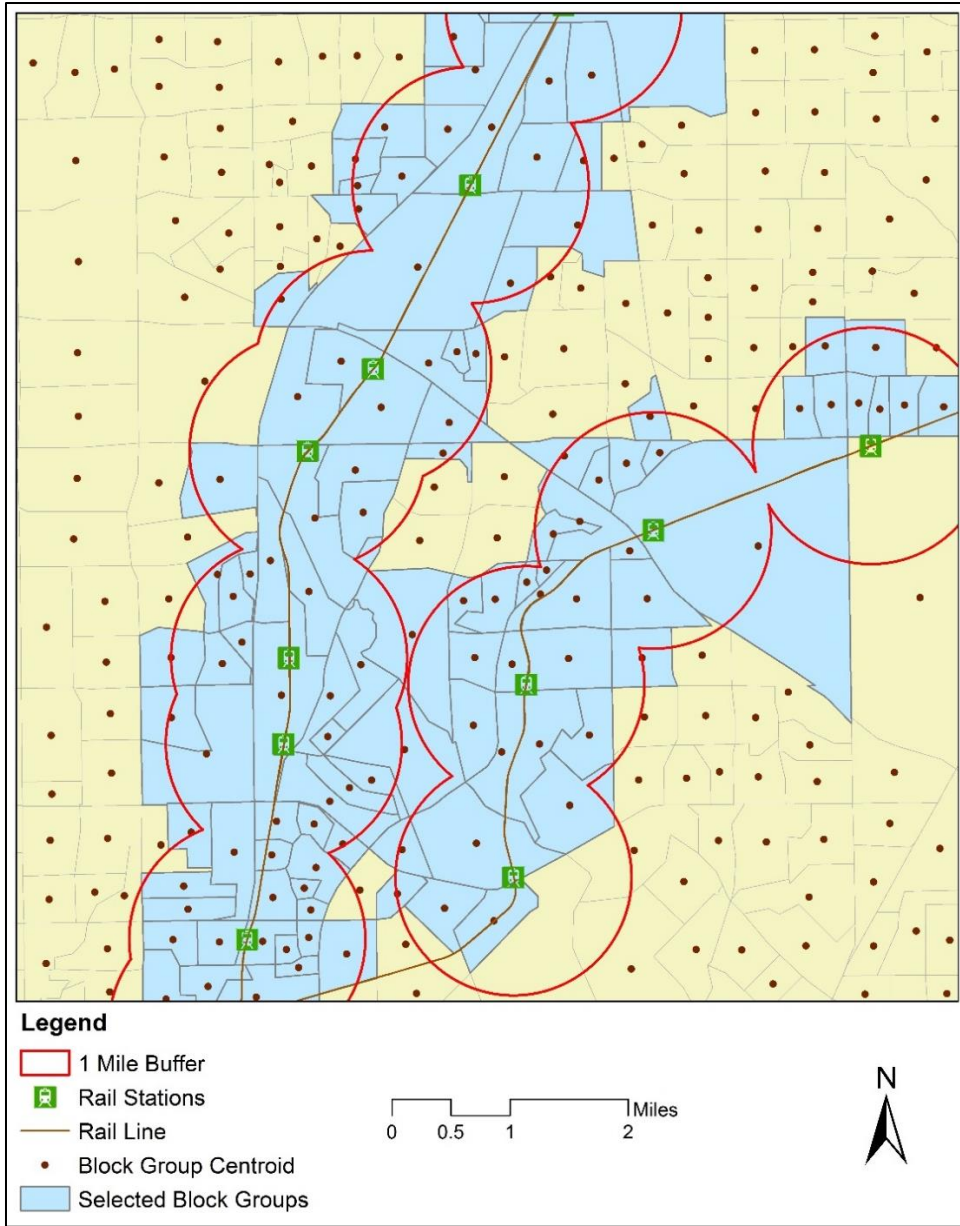
Figure 3-4 Sample of selected block groups
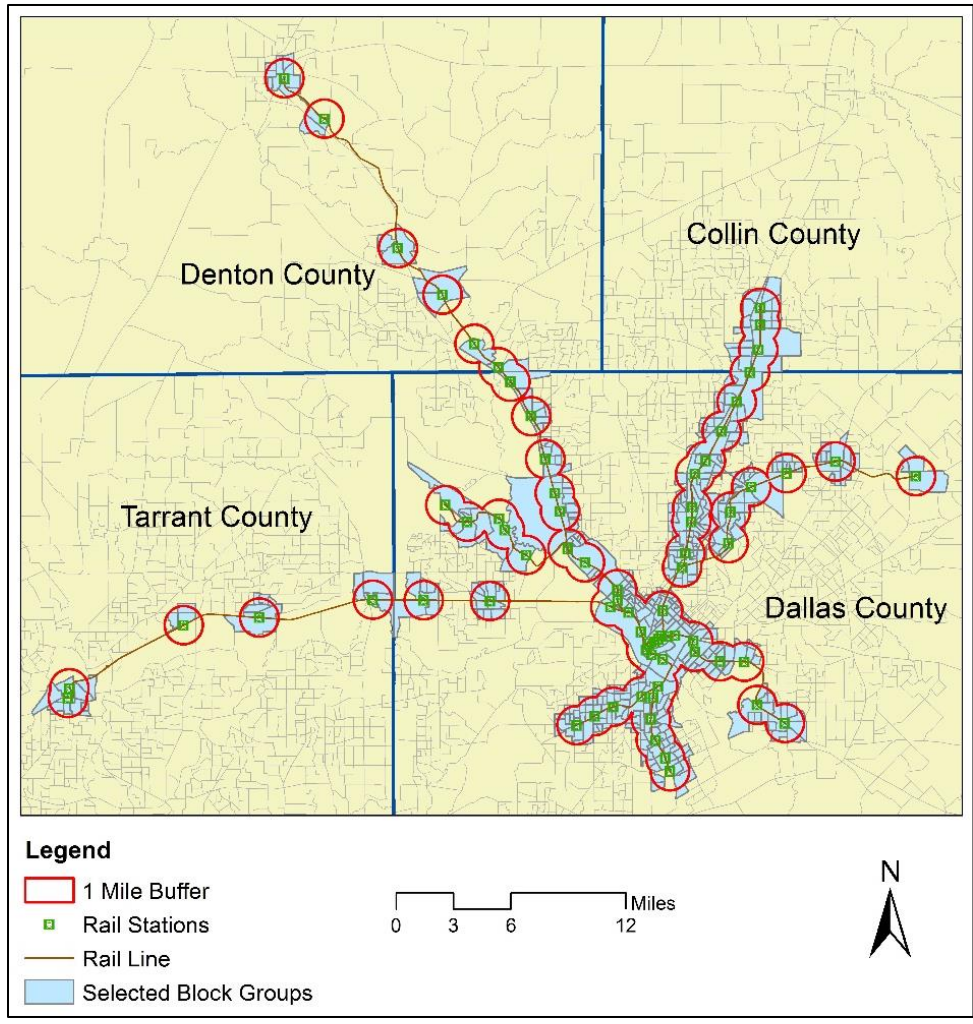
Figure 3-5 Block groups within one-mile radius from rail transit stations

3.3 Spatial Analysis and Statistical Tests

Chapter 2, Review of the Literature, shows the contribution of different authors and the major areas of knowledge that we are dealing with. This study tries to explain how it relates to the prior work and how it represents a new and significant contribution in the field of urban planning. In the previous work, multiple different types of approaches were used to measure the economic, social, and spatial impacts of proximity to rail stations on the surrounding area:

- Hedonic price models: This approach was developed by Rosen in 1974, and is a multiple regression model that includes explanatory variables mainly related to the location, quality of the

neighborhood, and property structure (Rosen, 1974). Several of the previous studies on the impact of rail stations on surrounding areas used this method since it is the most accurate and can determine the other factors that may contribute to an effect on the dependent variable. Also, Hedonic regression breaks down the contribution of independent variables by the value they contribute to the value of the dependent variable.

- Before-and-after method: This method is based on comparing two periods of time, documenting the changes in the study area before and after a particular event (Ge et al., 2012). Ge et al. (2012) argued that the main limitation of this study is that the time of actual impact may take a long time to occur and is unpredictable.

- Matched-pair comparisons: This method compares the study area to another one that has the same characteristics of the study area, but it is not close to rail station. The most common limitation of this method is finding a suitable pair of properties to compare that have the similar market characteristics (Golub, et al., 2011; Arndt et al., 2009).

- Hybrid methods: Some previous studies used more than one method to explore the impact of urban rail stations. For example, a couple of the studies used both the before-and-after method and a regression model. Others used matched-pair comparisons and two regression models – one for the transit area and the other for a non-transit area.

This study will use three approaches. First, this study will use the before and after method to compare the changes in some economic, social, and spatial factors within block groups located within one mile of the stations, the study area, between 2000 and 2014. The second method is a matched-pair analysis. This method will be used to do a comparison of the study area to the rest of block groups located within the four counties served by rail transit system in 2000 and 2014 which can be called "non-station areas". Finally, these will be followed by multiple regression models that will try to reject the null hypotheses and answer the research questions.

3.3.1 Comparison of Changes Between 2000 and 2014

Computing the economic, social, and spatial changes between 2000 and 2014 is one of the major techniques to understand the impact of rail transit systems on the surrounding area. The period between

2000 and 2014, is considered a long enough period that the impact can be observed and easily measured. Instead of measuring the actual impact over the time (2000-2014), a percent change can be used because it shows the magnitude of the absolute change in relation to the original value (the starting year) (Wang & Hofe, 2008). In this study, the starting year is 2000 and the ending year is 2014. For instance, the percent change in population between 2000 and 2014 can be calculated based on the following formulae:

$\%\Delta\ Pop_{2000\text{-}2014} = (Pop_{2014} - Pop_{2000})\ /\ Pop_{2000} * 100$

Where:

$\%\Delta\ Pop_{2000\text{-}2014}$: is percent change in population between 2000 and 2014

(3-1)

Pop_{2014}: total population of 2014

Pop_{2000}: total population of 2000

This formula will be applied to all variables related to this study (dependent and independent variables). In addition, a comparison between changes in the study area and the changes in the rest of the block groups within the four counties served by transit systems (non-station areas) will be conducted to investigate the differences. Comparing the study area changes to non-station areas will allow the researcher to see if the patterns of changes within block groups next to rail stations are different from changes in the blocks outside of the study area. Kruskal-Wallis test, known as One-Way ANOVA, (Field, 2009) will be conducted to examine whether the variation among all percent changes of variables for the period between 2000 and 2014 in the study area and non-station areas are statistically significant or not.

3.3.2 Regression Models

Multiple regression models are one of the most accurate methods used to understand what independent variables affect the dependent variables. In each regression model, independent variables can be incorporated as needed to give more explanation of the dependent variable (Lewis-Beck, 1980). Coorley (1978) stated, "The purpose of the statistical procedures is to assist in establishing the plausibility of the theoretical model and to estimate the degree to which the various explanatory variables seem to be

72

influencing the dependent variable" (p. 13). This section shows different sets of independent variables that will be examined and analyzed to answer the research questions.

3.3.2.1 Regression equation for research question 1:

Question 1 seeks to determine the changes in median housing value within a one-mile buffer around rail stations for the period between 2000 and 2014. Regression Equation 1 can be written as:

Change in median housing value (2000-2014) = f (transportation accessibility variables, socioeconomic attributes variables, location attributes variables, proximity to amenities variables).

$$(3\text{-}2)$$

The dependent variable (or Y) for regression Equation 1 is the change of median housing value (ΔHousvalue). The data for the median housing value (2000-20014) can be derived from the 2000 Census and the ACS 2010–2014. The independent variables for Equation 1 are categorized into variable regarding transportation accessibility, socioeconomic characteristics of residents, location attributes, and proximity to amenities. Each category has several explanatory variables that will be applied to all block groups within a one-mile radius from identified rail stations. The section below explains all of the independent variables behind each category:

- Transportation accessibility variables:
  - Distance from the centroid of each selected block group to the nearest rail station in the study area (Dis2station): Distance can be computed using the ArcGIS tool to find the shortest straight-line distance from the block group's center to the closest rail station. It is expected that as the distance from a rail station increases, that will lead to a lower change in housing value, a negative relationship.
  - Distance from the centroid of the selected block group to the nearest highway access ramp (Dis2Hgy): This variable will calculate the shortest straight-line distance from the nearest highway access ramp to the center of each block group. It is expected that as the distance from highway access ramp increases, that will lead to a greater change in housing value, a positive relationship.

- Distance to nearest downtown (Dis2Down): The distance can be calculated from the centroid of each block group to the nearest downtown. The downtowns of seven cities are found within the study area or surround it. I expect that as the distance from the closest downtown increases, the change in housing value will be smaller, a negative relationship.

- Socioeconomic characteristics of residents variables: (from 2000 and 2010–2014 ACS)

  - Change in income (ΔIncom) of the residents 16 years and older (2000-2014). I expect that as income increases over time that will lead housing value change to be larger, a positive relationship.

  - Change in number of residents, 25 years and older, with at least a bachelor's degree (ΔCollege) (2000-2014). It is expected that as the changes in the number of college educated residents increases over time, that will lead to a higher change in housing value, a positive relationship.

  - Change in number of civilian employed residents 16 years and older (ΔEmplyed) (2000-2014). It is expected that as the changes in the number of employed residents increases over time, that will lead to a higher change in housing value, a positive relationship.

  - Change in number of black residents (ΔBlk) (2000-2014). It is expected that as the changes in the number of black residents increases over time, that will lead to a lower change in housing value, a negative relationship.

  - Change in number of Hispanic and Latino residents (ΔHisp) (2000-2014). I expect that as the number of Hispanic and Latino residents increases over time that will lead housing value change to be lower, a negative relationship.

- Location attributes variables:

  - Change in population density (ΔPopDens) (2000-2014). In this study, the population density will be represented as the number of people per acre. I expect that as the change in population density increases over time that will lead housing value change to be larger, a positive relationship.

- Change in the number of jobs (ΔJob). Data about total jobs within each block group can be derived from the LEHD from 2002 to 2014. It is expected that as the change in the number of jobs increases over time, that will lead to a greater change in housing value, a positive relationship.

- Development patterns variables (Dum_TOD): neighborhoods next to rail stations have been developed either as a transit-oriented development (TOD) or non-TOD. The type of development patterns can be found in the NCTCOG, DART, DCTA, and TRE datasets. Thus, the dummy variables, which will represent both development patterns, will be introduced as shown in Table 3-1, and the TOD block group will be used as the reference case. I expect that developing neighborhoods next to stations as TODs lead to a greater change in housing value, a positive relationship.

Table 3-1 Dummy variable for development patterns

	Dum_TOD
TOD block group	1
Non-TOD block group	0

- Availability of park-and-ride facilities: The data related to this variable (Dum_RidPark) can be derived from NCTCOG databases. This variable will be introduced as shown in Table 3-2. I could not expect the relationship between the availability of parking lots next to rail stations and the change in housing value since parking lots have different impacts on the surrounding area.

Table 3-2 Dummy variable for park-and-ride facilities next to stations

	Dum_RidPark
Station with Park-and-Ride	1
Station without Park-and-Ride	0

- Proximity to amenities variables:
  - All data related to proximity to amenities and disamenities can be derived from the GIS shapefiles provided by NCTCOG. Shortest straight-line distances will be measured from the

centroid of each block group to the nearest amenity. The main independent variables related to this category are:

- o Distance to closest school (Dis2School). Based on NCTCOG classification, schools are divided into primary, private, and secondary schools. I expect that as the distance to school increases, the change in housing value decreases, a negative relationship.

- o Distance to closest shopping mall (Dist2mall). I could not expect the relationship between the distance to closest shopping mall and the change in housing value since shopping malls have various impacts on the surrounding area.

- o Distance to closest park (Dist2park). I expect that as the distance from park increases, the change in housing value decreases, a negative relationship.

Therefore, in mathematic terms, the first regression model is written as:

Δ median housing value (2000-2014) $= \alpha + \beta_1$ (Dis2station) $+ \beta_2$ (Dis2hgy) $+ \beta_3$ (Dis2Down) $+ \beta_4$ (ΔIncome) $+ \beta_5$ (ΔCollege) $+ \beta_6$ (ΔEmplyed) $+ \beta_7$ (ΔBlk) $+ \beta_8$ (ΔHisp) $+ \beta_9$ (ΔPopDen) $+ \beta_{10}$ (ΔJob) $+ \beta_{11}$ (Dum_TOD) $+ \beta_{12}$ (Dum_RidPark) $+ \beta_{13}$ (Dis2School) $+ \beta_{14}$ (Dis2Park) $+ \beta_{15}$ (Dis2Mall)

(3-3)

Table 3-3 below presents the four categories with all explanatory variables behind each category, along with definition, data source, and the sign of their expected impact on the median change in housing value. Here, a positive (+) sign indicates that it is expected to have positive relationship with the dependent variable. A negative sign (-) means a hypothesized negative relationship between the dependent and independent variable, and (?) means uncertain relationship.

Table 3-3 Definition of variables used in the Equation 1

Variable abbreviation	Definition	source	Expected sign
Dependent Variable			
ΔHousvalue	Change in median housing value (2000-2014)	2000 census - ACS 2010-2014	
Independent Variables			
Transportation accessibility Variables			
Dis2station	Distance from the centroid of the block group to the nearest rail station (miles)	NCTCOG	-
Dis2hgy	Distance from the centroid of the block group to the nearest highway access ramp (miles)	NCTCOG	+
Dis2Down	Distance to nearest city downtown (miles)	NCTGOC	-
Socioeconomic attributes variables			
ΔIncome	Change in income of the residents 16 years and older (2000-2014)	2000 census - ACS 2010-2014	+
ΔCollege	Change in residents 25 years and older with at least bachelor's degree (2000-2014)	2000 census - ACS 2010-2014	+
ΔEmplyed	Change in employed residents in civilian labor force (2000-2014)	2000 census - ACS 2010-2014	+
ΔBlk	Change in black residents (2000-2014)	2000 census - ACS 2010-2014	-
ΔHisp	Change in Hispanic or Latino residents (2000-2014)	2000 census - ACS 2010-2014	-
Location attributes variables			
ΔPopDen	Change in population density (2000-2014)	2000 census - ACS 2010-2014	+
ΔJob	Change in jobs (2002-2014)	LEHD	+
Dum_TOD	TOD or non-TOD (Dummy variable)	NCTCOG	+
Dum_RidPark	Availability of park-and-ride facilities (Dummy variable)	NCTCOG	?
Proximity to amenities variables			
Dis2School	Distance to nearest school (miles)	NCTGOC	-
Dis2Park	Distance to nearest park (miles)	NCTGOC	-
Dis2Mall	Distance to nearest shopping mall (miles)	NCTGOC	?

When building regression models, authors present at least one hypothesis, the null hypothesis (H_o), that assumes that a variable does not have an effect. Often, authors will present a second hypothesis that will be tested if the null hypothesis is proven false—which is an alternative hypothesis (H_a).

The null hypothesis (H_0: $\beta = 0$) for research question 1 might be written as: There is no relationship between the change in housing value (2000-2014) and distance to the nearest rail station in

the DFW area. However, the alternate hypothesis (H_a: β ≠ 0) is: there is a relationship between the change in in housing value (2000-2014) and distance to rail station in the DFW area.

3.3.2.2 Regression equation for research question 2:

Research question 2 is related to the race of residents living in proximity to rail stations. Research question 2 is: What has been the impact of existing rail stations on the racial make-up of residents in neighborhoods surrounding rail transit stations for the period between 2000 and 2014? Do rail stations attract more white residents to live next to rail transit stations? What are the other controlling factors affecting these attributes in proximity to rail stations? This question focuses on the change in the number of white residents for the period between 2000 and 2014 in the block groups within the one-mile buffer around rail stations. The regression Equation 2 for the changes in the number of white residents is:

Change in white residents (2000-2014) = f (transportation accessibility variables, socioeconomic attributes variables, housing market variables, location attributes variables)

(3-4)

The dependent variable (or Y) for regression Equation 2 can be derived from the 2000 Census and ACS 2010–2014. Also, the independent variables (explanatory) are categorized by transportation accessibility, socioeconomic characteristics of residents, housing market variables, and location attributes. These variables can be identified as some of the factors that can affect the race of population living near rail stations. Each category has some detailed variables, so all of the variables will be applied for all block groups within one mile from stations. Most of the independent variables are similar to the variables in regression Equation 1 except that in this equation, the proximity to amenities variables has been eliminated since they do not have a major effect on the dependent variable (ΔWhite), but housing market variables (median housing value and rent) have been added because they may affect the changes in race. Therefore, the second regression function is:

Δ white residents (2000-2014) = α + $β_1$ (Dis2station) + $β_2$ (Dis2hgy) + $β_3$
(Dis2Down) + $β_4$ (ΔIncome) + $β_5$ (ΔCollege) + $β_6$ (ΔEmplyed) + $β_7$ (ΔBlk) + $β_8$
(ΔHisp) + $β_9$ (ΔHousvalue) + $β_{10}$ (ΔRent) + $β_{11}$ (ΔPopDen) + $β_{12}$ (ΔJob) + $β_{13}$ (3-5)
(Dum_TOD)

Table 3-4 below presents the four categories with their explanatory variables, along with definition, data source, and the sign of their expected impact on the change in the number of white residents.

Table 3-4 Definition of variables used in the Equation 2

Variable abbreviation	Definition	source	Expected sign
	Dependent Variable		
ΔWhite	Change in the number of white residents (2000-2014)	2000 census - ACS 2010-2014	
	Independent Variables		
	Transportation accessibility variables		
Dis2station	Distance from the centroid of the block group to the nearest rail station (miles)	NCTCOG	-
Dis2hgy	Distance from the centroid of the block group to the nearest highway access ramp (miles)	NCTCOG	+
Dis2Down	Distance to nearest city downtown (miles)	NCTGOC	+
	Housing market variables		
ΔHousvalue	Change in median housing value (2000-2014)	2000 census - ACS 2010-2014	+
ΔRent	Change in median contract rent for housing units (2000-2014)	2000 census - ACS 2010-2014	+
	Socioeconomic variables		
ΔIncome	Change in income of the residents 16 years and older (2000-2014)	2000 census - ACS 2010-2014	+
ΔCollege	Change in residents 25 years and older with at least bachelor's degree (2000-2014)	2000 census - ACS 2010-2014	+
ΔEmplyed	Change in employed residents in civilian labor force (2000-2014)	2000 census - ACS 2010-2014	+
ΔBlk	Change in black residents (2000-2014)	2000 census - ACS 2010-2014	-
ΔHisp	Change in Hispanic and Latino residents (2000-2014)	2000 census - ACS 2010-2014	-
	Location attributes variables		
ΔPopDen	Change in population density (2000-2014)	2000 census - ACS 2010-2014	?
ΔJob	Change in job (2002-2014)	LEHD	?
Dum_TOD	TOD or non-TOD (Dummy variable)	NCTCOG	+

The null hypothesis (H$_0$: β = 0) for research question 2 can be written as: There is no relationship between the change in the total number of white residents (2000-2014) and distance to the nearest rail station in the DFW area. However, the alternate hypothesis (H$_a$: β ≠ 0) is: There is a relationship between the change in the total number of white residents (2000-2014) and distance to the nearest rail station in the DFW area.

3.3.2.3 Regression equation for research question 3:

Research question 3 takes into account the change in population density for the period between 2000 and 2014 in block groups located within one-mile buffer around rail transit stations in the DFW area. The regression Equation 3 is of the following form:

Change in population density (2000-2014) = f (transportation accessibility variables, socioeconomic attributes variables, housing market variables, location attributes).
(3-6)

The dependent variable (or Y) for regression Equation 3 is that the change in population density can be derived from GIS shapefiles provided by NCTCOG database, the 2000 Census, and the ACS 2010-2014 for each block group located within one-mile radius from rail transit stations in the DFW area. In addition, the independent variables (explanatory) are categorized by transportation accessibility, socioeconomic characteristics of residents, housing market, and location attributes. These variables can be identified as some of the factors that affect the changes in population density within neighborhoods surrounding rail stations. Each category has some variables, so all of the variables will be applied to all selected block groups. Most of the independent variables are similar to the variables in previous regression equations except that in this equation, the proximity to amenities and some variables related to the socioeconomics and location attributes have been eliminated since they do not have major effect on the dependent variables. However, changes in housing land value, changes in distance to major employer, and changes in the rate of poverty level have been added because they may affect the dependent variables (ΔPopDen). Therefore, the third regression function is:

Δ in population density (2000-2014) = α + β_1 (Dis2station) + β_2 (Dis2hgy) + β_3

(Dis2Down) + β_4 (Dis2MajEmplo) + β_5 (ΔIncome) + β_6 (ΔEmplyed) + β_7 (ΔWhite)

+ β_8 (ΔHisp) + β_9 (ΔPoverty) + β_{10} (ΔHousValue) + β_{11} (ΔJob) + β_{12} (Dum_TOD)   (3-7)

+ β_{12} (Dum_RidPark)

Table 3-5 below presents the four categories and their explanatory variables, along with definition, data source, and the sign of their expected impact on the population density change.

Table 3-5 Definition of variables used in the Equation 3

Variable abbreviation	Definition	source	Expected sign
	Dependent Variable		
ΔPopDen	Change in population density (2000-2014)	2000 census - ACS 2010-2014	
	Independent Variables		
	Transportation accessibility Variables		
Dis2station	Distance from the centroid of the block group to the nearest rail station (miles)	NCTCOG	-
Dis2hgy	Distance from the centroid of the block group to the nearest highway access ramp (miles)	NCTCOG	-
Dis2Down	Distance to nearest city downtown (miles)	NCTGOC	-
Dis2MajEmplo	Distance to closest major employers	NCTCOG	?
	Socioeconomic attribute variables		
ΔIncome	Change in income of the residents 16 years and older (2000-2014)	2000 census - ACS 2010-2014	-
ΔEmplyed	Change in employed residents in civilian labor force (2000-2014)	2000 census - ACS 2010-2014	-
ΔWhite	Change in white residents (2000-2014)	2000 census - ACS 2010-2014	-
ΔHisp	Change in Hispanic and Latino residents (2000-2014)	2000 census - ACS 2010-2014	+
ΔPoverty	Change in poverty status of households (2000-2014)	2000 census - ACS 2010-2014	+
	Housing market variables		
ΔHousvalue	Change in median housing value (2000-2014)	2000 census - ACS 2010-2014	+
	Location attributes variables		
ΔJob	Change in job (2002-2014)	LEHD	-
Dum_TOD	TOD or non-TOD (Dummy variable)	NCTCOG	+
Dum_RidPark	Availability of park-and-ride facilities	NCTCOG	?

The null hypothesis (H_0: $\beta = 0$) for the research question 3 might be written as: There is no relationship between the change in population density (2000-2014) and distance to the nearest rail station in the DFW area. However, the alternate hypothesis (H_a: $\beta \neq 0$) is: There is a relationship between the change in population density (2000-2014) and distance to the nearest rail station in the DFW area.

To conclude, in examining the set of dependent variables impacted by rail stations, a good number of independent variables from social and economic theories and the literature review will be used to answer the research questions. All models have many independent variables, but models will follow the process of building the best appropriate regression model. Building a model is a complicated process that requires many statistical procedures such as a test of the normality, a test of the multicollinearity, a test of homoscedasticity, and data transformation. Choosing the best model is based on some criteria (Anjomani, 2016; Berenson, Levine & Krehbiel, 2009). SPSS software can help to carry out most of the process until finding the best regression model.

Chapter 4

Descriptive Analysis and Results

This chapter begins with a discussion about the changes or the differences in economic, social, and spatial factors of the selected block groups that are located within a one-mile buffer around rail stations between 2000 and 2014, which are related to the research questions. Then, a comparison will be conducted to investigate the differences in changes between the study area (the block groups within a one-mile buffer around stations) and non-station areas (the rest of the block groups within the four counties served by rail transit systems in the DFW area). Comparing the study area to non-station areas will allow the researcher to see whether the patterns of changes within block groups next to rail stations differ from changes in the block groups outside the study area. This chapter provides a discussion about whether the block groups experience positive or negative changes between 2000 and 2014, either within a one-mile radius around rail stations or outside the study area. This is followed by a section illustration of the various distances between the selected block groups within one-mile buffer and some spatial factors that may affect research questions such as distance to highway ramps, schools, downtowns, major employers, shopping malls, and parks. In addition, some location attributes will be discussed such as the availability of park and ride facilities and whether the rail station was developed as a TOD or a non-TOD.

4.1 Descriptive Statistics

Data from various sources including the 2000 U.S. Census, ACS 2010-2014, and ArcGIS database of the NCTCOG Regional Data Center will be collected and joined; then, the selected block groups within the one-mile buffer around rail transit stations within the four counties will be extracted from the rest of the block groups to be analyzed. The study area contains 454 block groups: 396 block groups are located within Dallas County, 19 block groups are in Tarrant County, 20 block groups are in Collin County, and 19 block groups in Denton County. As mentioned earlier, the study area has 74 rail stations; 32 rail transit stations were developed as transit-oriented development (TOD), whereas 42 stations can be considered as non-TODs. Furthermore, park-and-ride facilities are available next to 47 rail stations within the study area, while 27 stations lack parking facilities. This means that 224 block groups located within one mile from stations were developed as a TOD, and 326 block groups surround rail stations have

park-and-ride facilities. Below is an analysis of the percent change of all socioeconomic attributes of residents, housing markets, and location variables that are expected to affect the dependent variables; this part is followed by a comparison between the study area and non-station areas. The last section is about the distances to some locations and amenities that may also influence dependent variables.

4.1.1   Comparison of Study Area Changes between 2000 and 2014

This section discusses the changes between 2000 and 2014 in the dependent variables and factors that may contribute in affecting those dependent variables. Percent change will be used to show the degree of changes in the selected variables over time. Table 4-1 shows the economic, social, and location factors and their medians in 2000 and 2014, the median percent changes between the starting and ending years (2000-2014), and the number of block groups that experienced negative, positive, and zero percent change. The median value is used since all variables have extreme values. Thus, the median is better because it is not as sensitive to extreme values.

Table 4-1 shows that block groups surrounding rail transit stations did not experience a major increase in the total population in the period between 2000 and 2014, since many residents continue to move to the outlying areas. The median of the population in 2000 was 1,177 persons per block group, which increased to 1,241 in 2014, a very small increase. Almost slightly more than half of the block groups within the study area experienced a negative percent change between 2000 and 2014, most of which were located within the area south and northeast of downtown Dallas and the surrounding areas near the Bachman, downtown Irving, and downtown Denton stations. However, a major increase in total population can be noticed in downtown Dallas, near north stations, and in some block groups within stations in Irving city as shown in Figure 4-1. The median population density (the number of population per acre) grew slightly from eight persons per acre in 2000, to nine persons per acre in 2014; 218 block groups show a negative percent change, while 236 shows positive percent change in population density. Generally, both positive and negative percent change have a scattered distribution with some concentration of negative changes in the block groups located to the south and northeast of downtown Dallas as shown in Figure 4-2.

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The changes in the number of white residents showed an increase from the median of 634 per block group in 2000 to 806 in 2014. The number of block groups that experienced positive percent change in the total white residents is 302, but 151 block groups showed a decline in the number of white residents as shown in Figure 4-3. Regarding black residents in the study area, their median increased from 109 to 127 persons per block groups between 2000 and 2014. The number of block groups that experienced a decline in black residents is 246 block groups, whereas 202 block groups showed an increase in the number of black residents. Six block groups did not experience any change in the number of black residents as shown in Figure 4-4. The number of white residents increased in the south Dallas while black residents declined within the same area. In addition, block groups next to rail stations in Irving experienced a greater increase of black residents and a major decline in white residents. A number of blocks within the study area also experienced an increase in the number of Hispanic and Latino residents. The median of this minorities increased from 289 persons per block group in 2000 to 381 persons in 2014. While 295 block groups experienced positive percent change in the number of Hispanic and Latino residents between 2000 and 2014, 156 block groups within the study area experienced a decline in the number of Hispanic and Latino residents—most of which, as shown in Figure 4-5, were in areas surrounding downtown Dallas and most of rail stations located northeast of the city.

The median number of residents who have a bachelor's degree or more grew from 103 persons per block group in 2000, to 124 persons in 2014, but 189 block groups out of 454 block groups showed a decline in college educated residents. The major increase of college educated residents is concentrated within downtown Dallas and expands northwest and west toward downtown Fort Worth as shown in Figure 4-6. Figure 4-7 shows the percent change of employed residents within the study area between 2000 and 2014. The median population of employed residents increased from 521 in 2000, to 567 persons per block group in 2014. 283 block groups experienced a positive percent change, but 206 block groups of the study area show a reduction in the number of residents who are employed, and most of block groups having more employed residents are located within downtown Dallas and extend toward the northwest and within downtown Fort Worth.

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The median number of jobs within each block group within the study area increased from 171 jobs in 2000, to 226 jobs in 2014. 253 block groups experienced positive percent change, while 184 lost jobs. Block groups experiencing an increase or decrease in the number of jobs are distributed randomly within the study area as shown in Figure 4-8. Percent change in residents' income within the study area shows a decline in the median of income from around $20,091 in 2000 to $18,122 in 2014, after an inflation adjustment to the 2000 dollar in the DFW area[1]. 177 block groups experienced a positive percent change, while 277 block groups show a decline in the median income of the residents as shown in Figure 4-9. The decrease of changes in income was distributed throughout the entire study area with more concentration in the area surrounding the southern, northeastern, and northwestern rail stations, whereas the positive change can be noticed within the area surrounding downtown Dallas and Irving as well as toward the northwest.

The median housing value in 2000, for block groups within the study area, was around $70,200, which increased to about $83,844 in 2014 (adjusted to housing price inflation of Dallas in terms of 2000 base year dollar)[2]. About 134 block groups experienced negative percent change, but 320 block groups showed a positive percent change in the median of housing value as shown in Figure 4-10. However, the median price of residential rent in 2000 was $530, which declined to $526 in 2014 (inflation adjusted to 2000 base year dollar for DFW area)[3]. Slightly less than half of the block groups within the study area, 220 block groups, showed an increase in residential rent, while 234 block groups experienced a decline in residential rent. Most of the block groups that experienced a negative percent change in residential rent are located within northeast rail stations as shown in Figure 4-11.

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1 Consumer Price Index all Urban Consumers (CPI-U) for DFW area is used to calculate dollar inflation ($1 in 2014 = $0.743 in 2000 year dollar)

2 Housing prices inflation is used to adjust housing values of 2014 to the 2000 base year dollar based on S&P CoreLogic Case-Shiller Dallas Home Price NSA Index ($1 in 2014 = $0.754 in 2000 year dollar)

3 Consumer Price Index all Urban Consumers (CPI-U) for DFW area is used to calculate dollar inflation ($1 in 2014 = $0.743 in 2000 year dollar)

Table 4-1 Descriptive statistics for variables of study area (454 block groups) between 2000 and 2014

Variables of selected block groups (BGs)	Median of BGs (2000)	Median of BGs (2014)	Median of %Δ in BGs (2000-2014)	# BGs Negative %Δ (2000-2014)	# BGs No change (2000-2014)	# BGs Positive %Δ (2000-2014)
Total population	1,177	1,241	1.50%	218	0	236
Population density (# of population per acre)	8	9	1.50%	218	0	236
White residents	634	806	22%	151	1	302
Black residents	109	127	-11%	246	6	202
Hispanic residents	289	381	29.27%	156	3	295
Residents with Bachelors& over	103	124	13.77%	189	4	261
Employed residents	521	567	3.91%	206	1	283
Number of jobs per BG	171	226	10.61%	184	17	253
Income of residents	$20,091	$24,390 ($18,122 in $2000)	-8.77%	277	0	177
Housing value	$70,200	$111,200 ($83,845 in $2000	13.87%	134	0	320
Housing rent	$530.50	$707 ($526 in $2000)	-0.72%	234	0	220
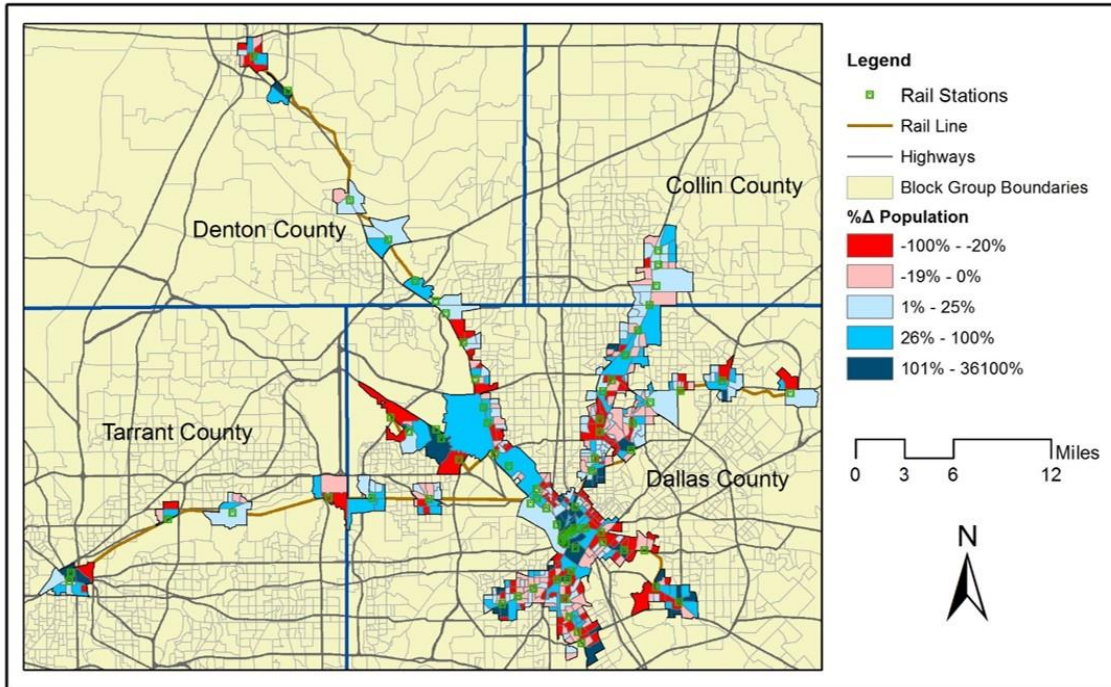
Figure 4-1 Percent change in total population in station areas between 2000 and 2014
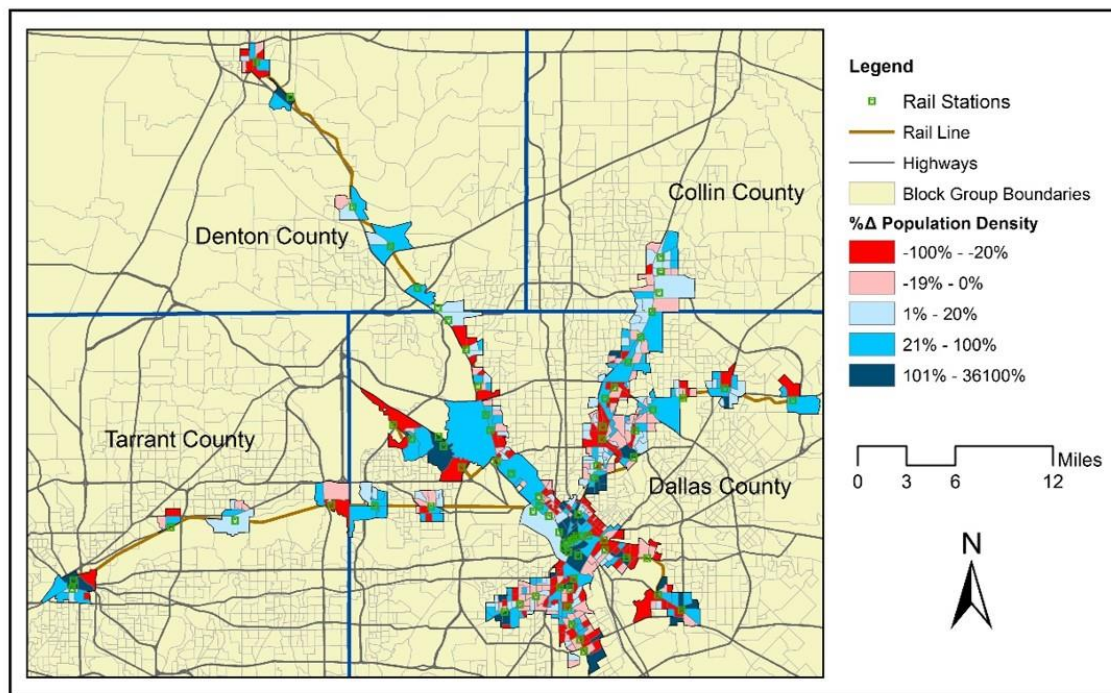
Figure 4-2 Percent change in population density in station areas between 2000 and 2014

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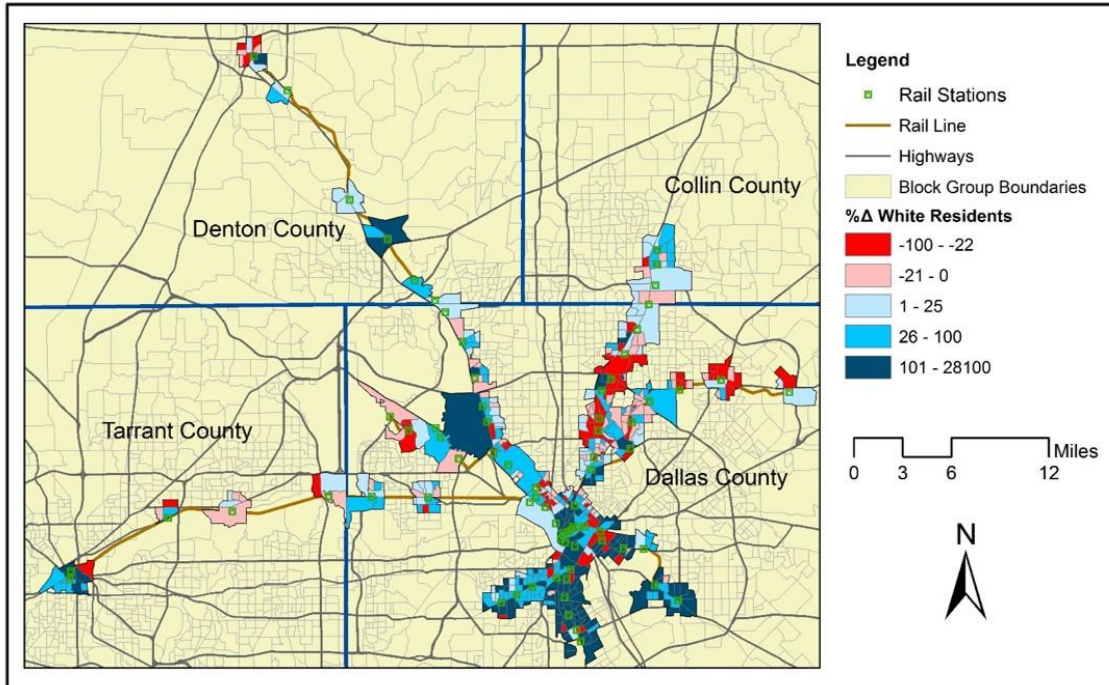
Figure 4-3 Percent change in white residents in station areas between 2000 and 2014
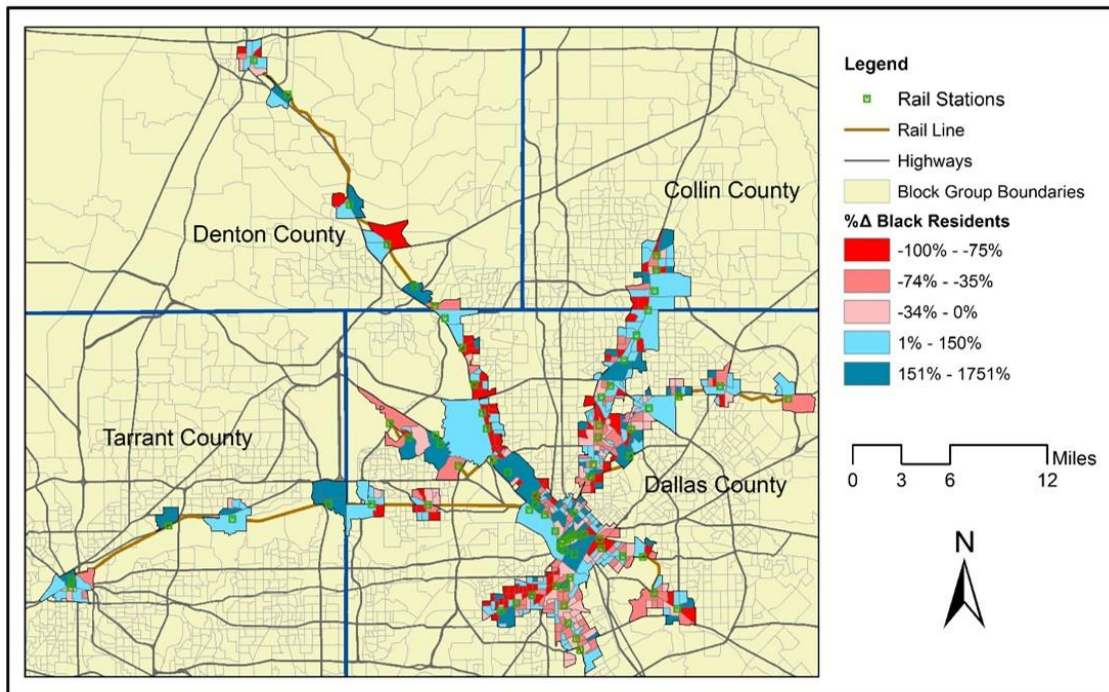
Figure 4-4 Percent change in black residents in station areas between 2000 and 2014
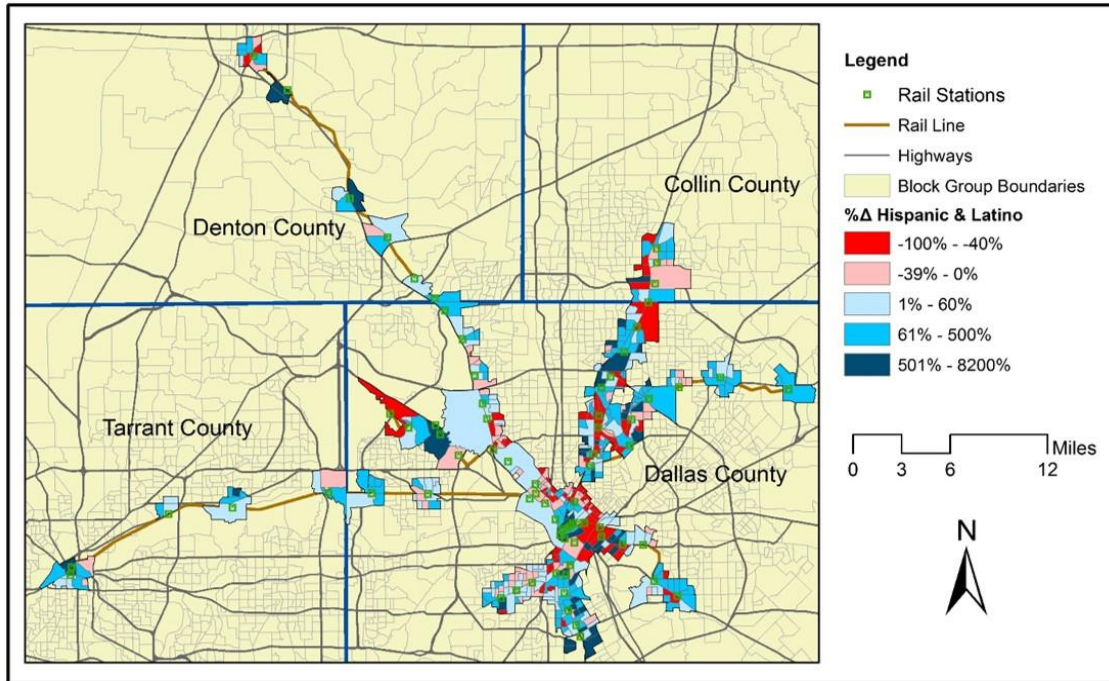
Figure 4-5 Percent change in Hispanic and Latino in station areas between 2000 and 2014
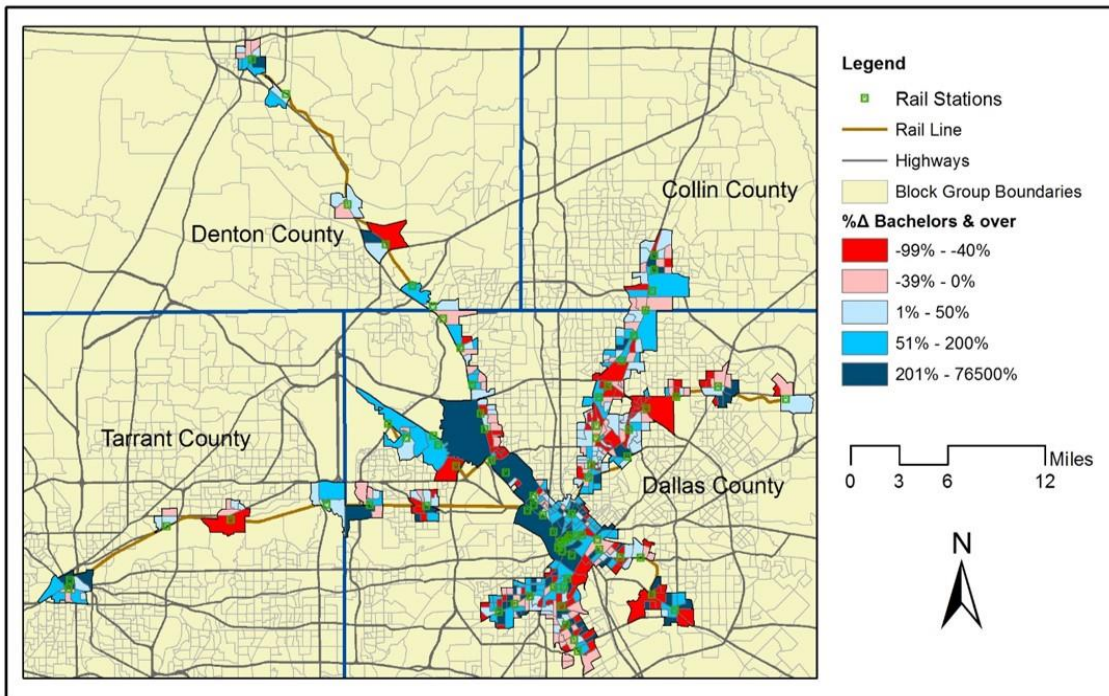
Figure 4-6 Percent change in college educated residents 2000 and 2014
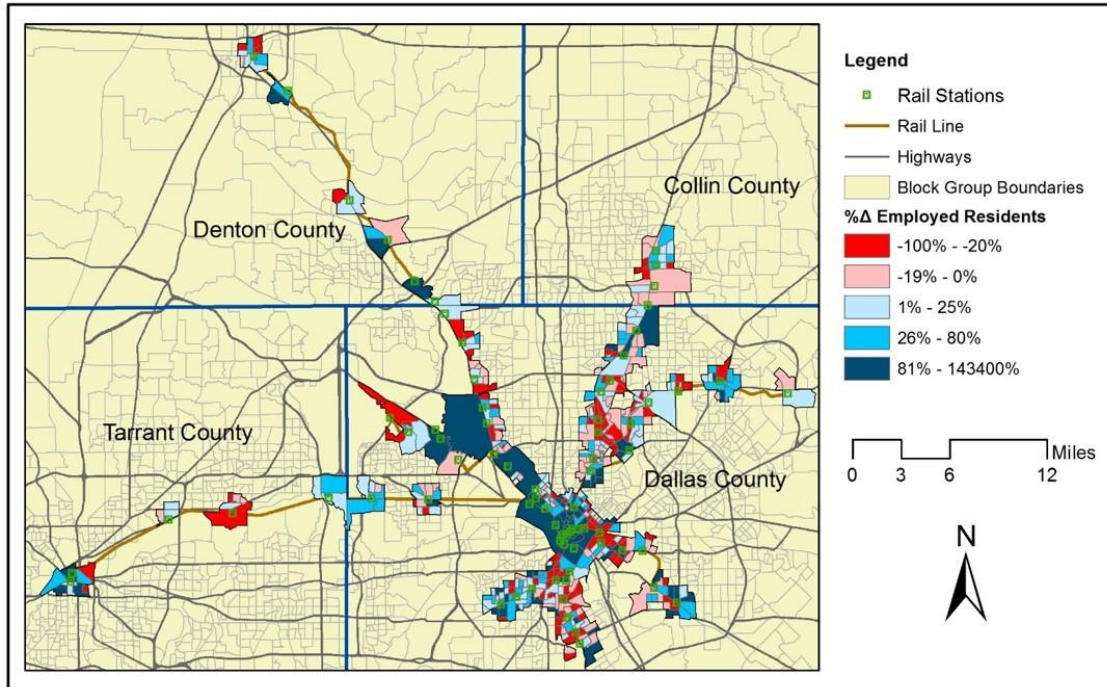
Figure 4-7 Percent change in employed residents in station areas between 2000 and 2014
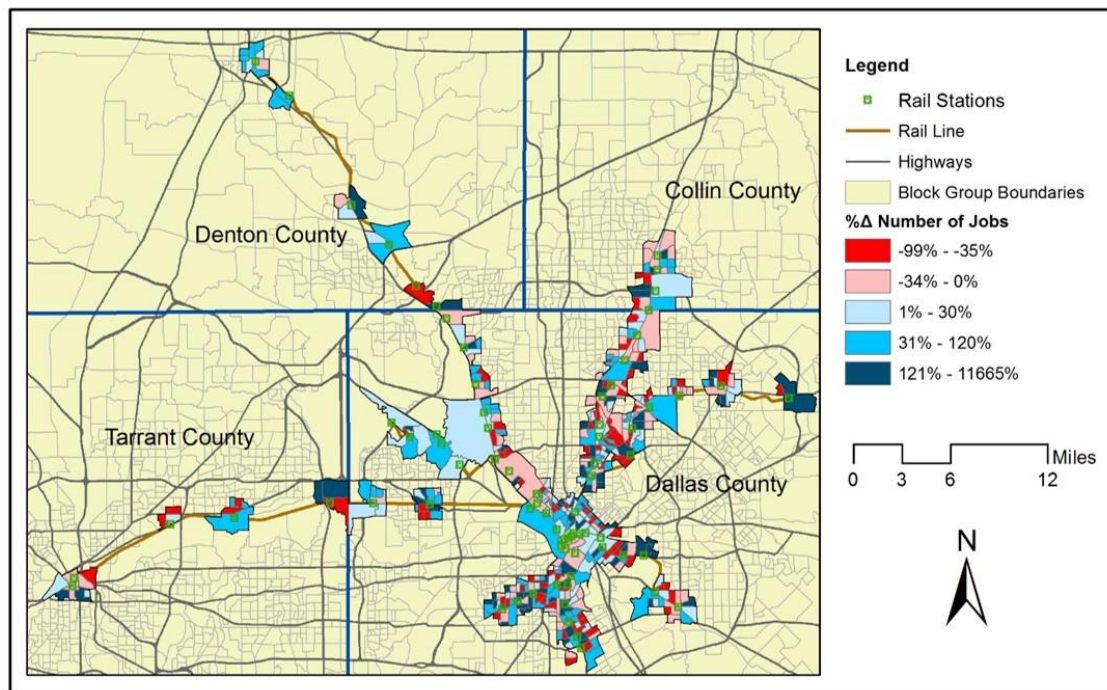
Figure 4-8 Percent change in number of jobs in station areas between 2002 and 2014
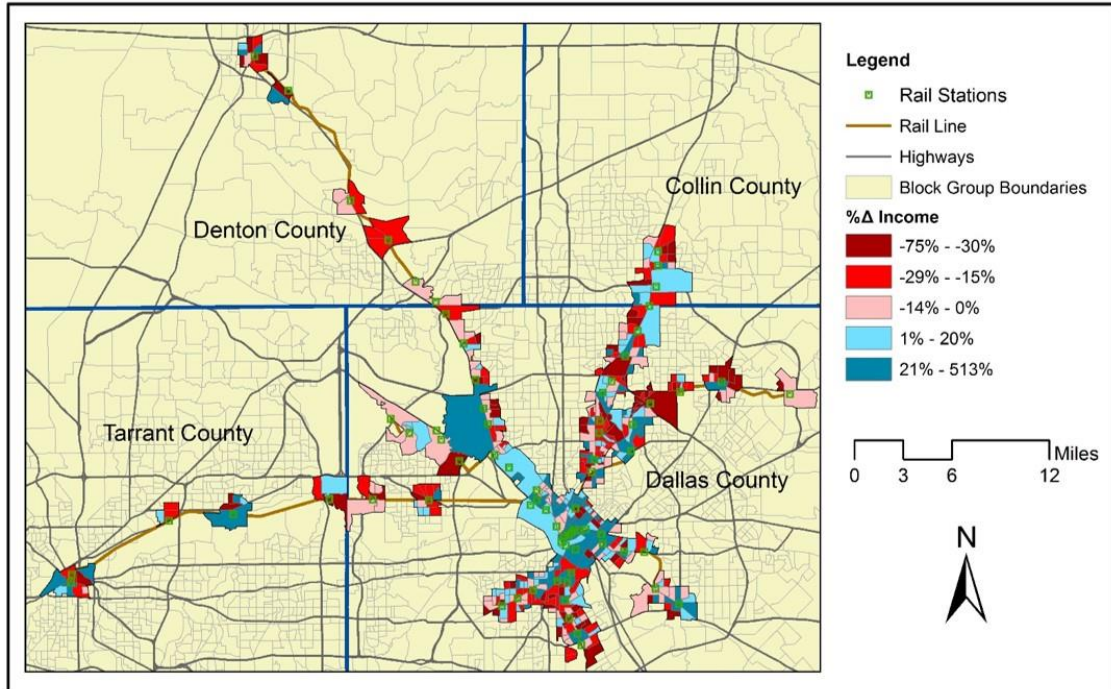
Figure 4-9 Percent change in residents' income in station areas between 2000 and 2014
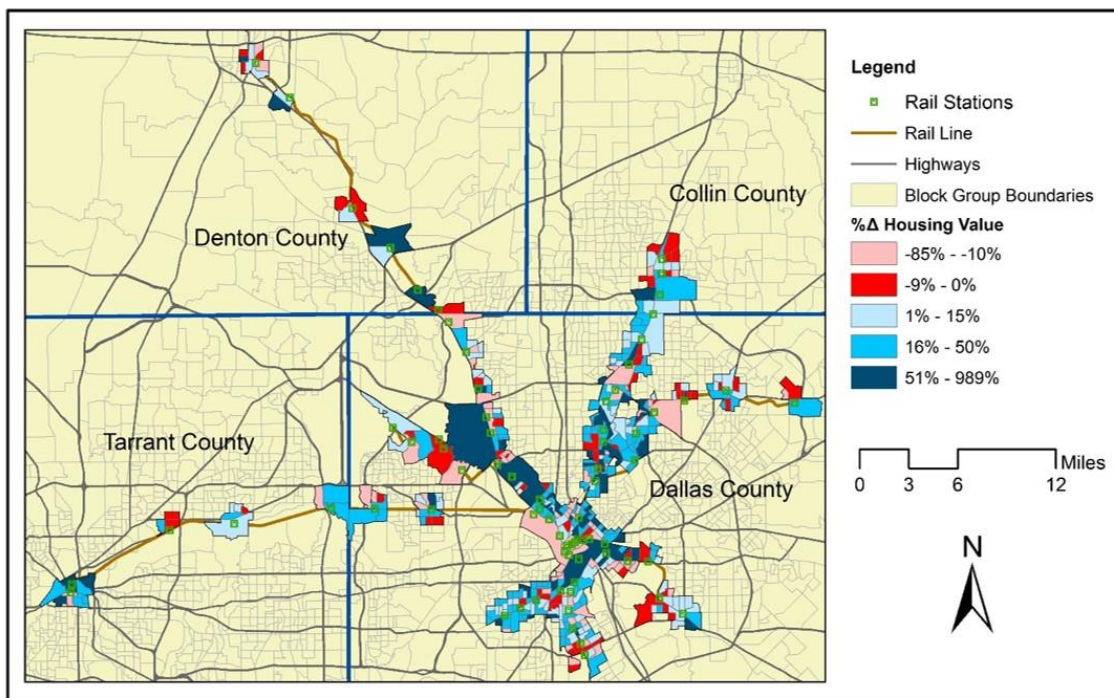
Figure 4-10 Percent change in housing value in station areas between 2000 and 2014
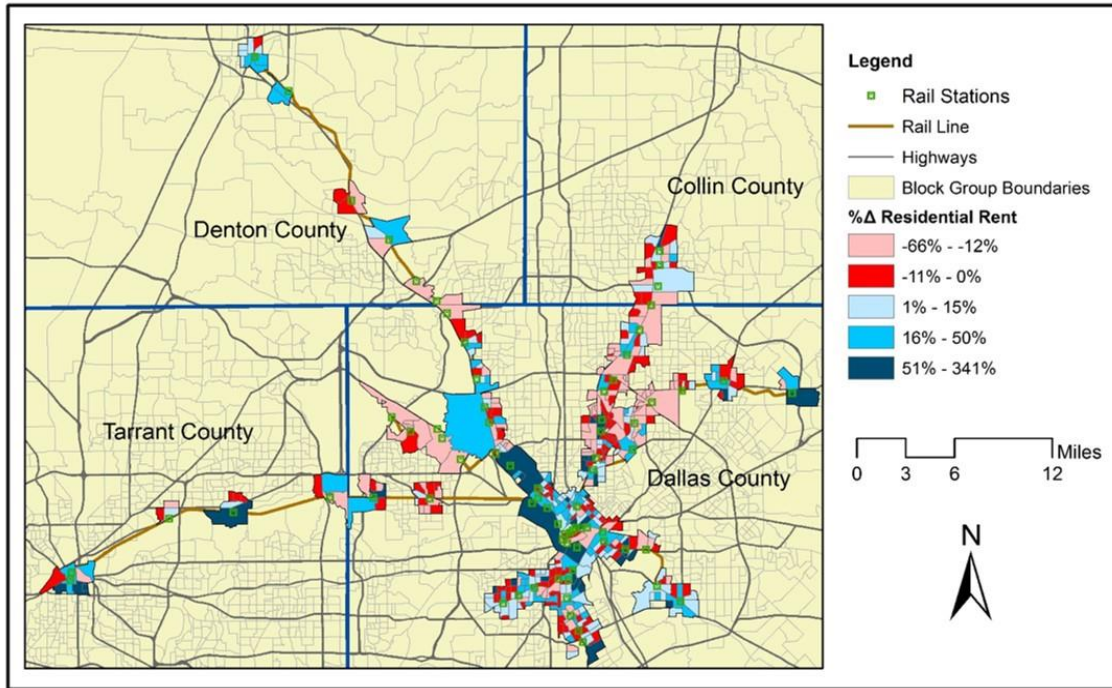
Figure 4-11 Percent change in median housing rent in station areas between 2000 and 2014

4.1.2   Comparison of the Study Area Changes and County Changes between 2000 and 2014

A comparison of the changes within the study area and the changes within the rest block groups located outside of the study area within the four counties will be conducted to investigate the differences in changes between block groups in proximity to rail stations and non-station block groups. Comparing the study area to the non-station block groups allows the researcher to see if the patterns of changes within block groups next to rail stations are different from changes in the block groups located in non-station areas. After adjusting the boundaries between 2000 and 2010 block groups, the four counties have a total of 3,064 block groups; as 454 block groups are located next to rail stations and selected as the study area, this means that there are 2,610 non-station block groups. The section below shows the results of Kruskal-Wallis test and the comparison between the two types of block groups.

As shown in table 4-2, all percent changes in the selected variables are statistically significant at 0.05 level of significant. This means there are statistically significant differences between the percent changes of the selected variables in block groups located within the study area and the rest of block groups located within the four counties served by rail transit systems.

Table 4-2 Kruskal-Wallis test results for different percent changes of selected variables

Test Statistics [a,b]			
	Chi-Square	df	Sig.
%Δpop	27.926	1	0.000
%Δpop_dens	27.985	1	0.000
%Δwhite	13.253	1	0.000
%Δblack	18.070	1	0.000
%Δhisp	52.202	1	0.000
%Δcollege	5.548	1	0.018
%Δemployed	5.148	1	0.023
%Δjob	5.806	1	0.016
%Δincome	8.008	1	0.005
%Δvalue	25.006	1	0.000
%Δrent	6.363	1	0.012
a. Kruskal-Wallis Test b. Grouping Variable: Station_Non-Station			

The comparison of station areas and non-station areas reveals the differences in changes that occurred between 2000 and 2014 as shown in Table 4-1 and Table 4-2. It can be observed that the median of the total population and the median of the population density in the block groups within the study area is smaller than the median of the total population and population density within the non-station areas. Within station areas, the median percent change in total population is about 1.50%, but in the non-station area, the median significantly increased to almost 10% between 2000 and 2014; similar figures can be noticed in the changes in population density both within the study area and outside the study area. Figure 4-12 and Figure 4-13 show a major increase in total population and population density between 2000 and 2014 within all block groups located in the four counties.

Figure 4-14 shows that between 2000 and 2014, the number of white residents grew significantly by the median of 22% per block group near rail stations compared to 9.65% in non-station block groups. Figure 4-15 shows that the median number of black residents significantly dropped by 11% per block group within study area compared to a 9.79% increase in the median for the non-station areas. In other

words, there was a greater increase of white residents within the station areas than non-station areas, whereas black residents declined considerably within the study area and increased in non-station areas, specifically in the outlying areas. Hispanic and Latino residents experienced a considerable increase outside the one-mile buffer of rail stations; the median of their percent change is about 94%, compared to an significant increase of 30% per block group within the study area as shown in Figure 4-16. College educated show a major change in differences between the study area and non-station areas. The median of the percent change of college educated residents is about 14% in the station areas and 18% outside the buffer as shown in Figure 4-17.

The change in employed residents between 2000 and 2014 within the study area is significantly smaller than the change in non-station areas as shown in Figure 4-18. The median of percent change, between 2000 and 2014, of employed residents in block groups next to rail stations was about 4% compared to 8.30% within the block groups outside the study area. The median of the percent change in the number of jobs within the study area is around half of the increase in the non-station areas. As shown in Figure 4-19, the median of percent change in the number of jobs per block group is about 11% within station areas compared to about 20% in non-station areas. It can be observed that a large number of jobs moved from the main cities toward the outlying areas during the study period.

After the adjustment for inflation, changes in income, housing value, and rent show interesting results. The median of residents' income, both within or outside the study area, declined as shown in Table 4-3. The median of percent change in income within the study area declined by approximately 9%, whereas the median of percent change of income in non-station areas was reduced by about 12% as shown in Figure 4-20. While the median housing value in 2000 and 2014 in non-station areas was greater than the study area, the change was larger when in proximity to rail stations; the median of percent change in housing value within the study area is 14% compared to 5% outside the study area. Figure 4-21 shows that the percent change in housing value follows a random distribution with some concentration in Denton County, the eastern part of Collin County, and the western part of Tarrant County. The median housing rent experienced a slight decline between 2000 and 2014 in both the study area and outside it, but the decline is greater in non-station areas. It can be observed that the median percent change

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decreased by around 1% within the study area and 4% within the non-station areas. Figure 4-22 shows

that the major increase in income occurred in the north and northwest outlying areas.

Table 4-3 Descriptive statistics for variables of non-station areas (2610 BGs) between 2000 and 2014

Variables for block groups (non-station areas)	Median of BGs (2000) (non-station areas)	Median of BGs (2014) (non-station areas)	Median of %Δ in BGs (2000-2014) (non-station areas)	Median of %Δ in BGs (2000-2014) (study area)
Total population	1,258	1,454	9.78%	1.50%
Population density (# of population per acre)	6	6.5	9.78%	1.50%
White residents	877	1,004	9.65%	22%
Black residents	72	119	9.79%	-11%
Hispanic or Latino residents	164	376	94.24%	29.27%
Residents with Bachelors& over	195	247	16.67%	13.77%
Employed residents	604	688	8.30%	3.91%
Number of jobs per BG	152	195	20.42%	10.61%
Income of residents	$27,363	$32,466 ($24,122 in $2000)	-12.06%	-8.77%
Housing value	$91,000	$130,000 ($98,020 in $2000)	4.93%	13.87%
Housing rent	$600	$800 ($595 in $2000)	-3.58%	-0.72%
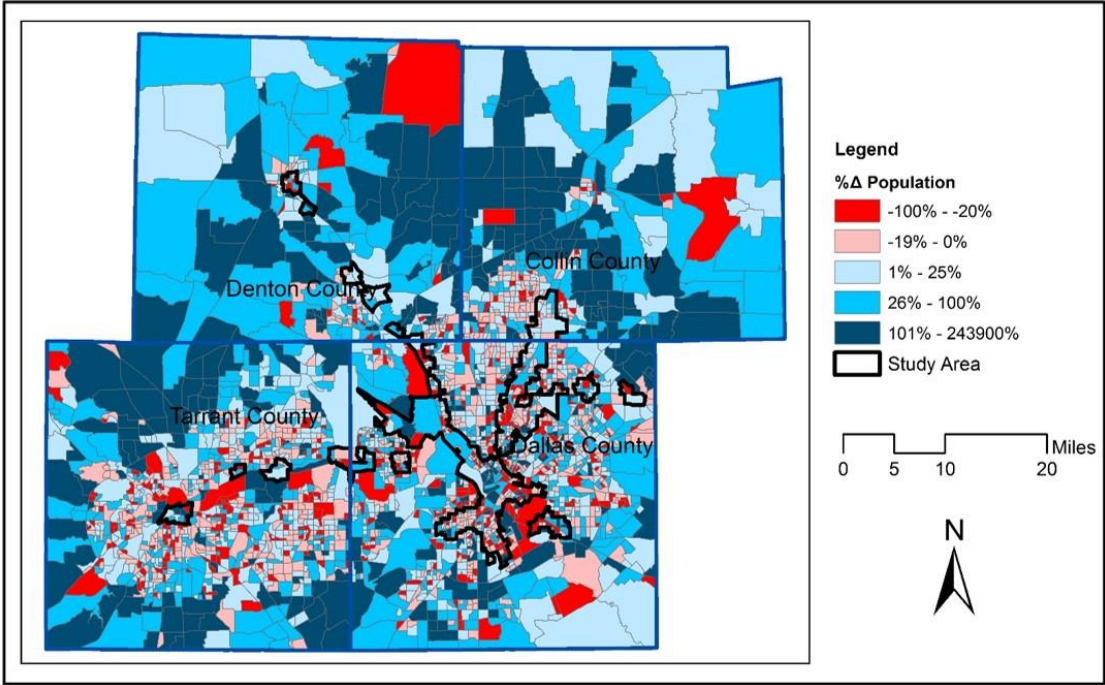
Figure 4-12 Percent change in total population between 2000 and 2014
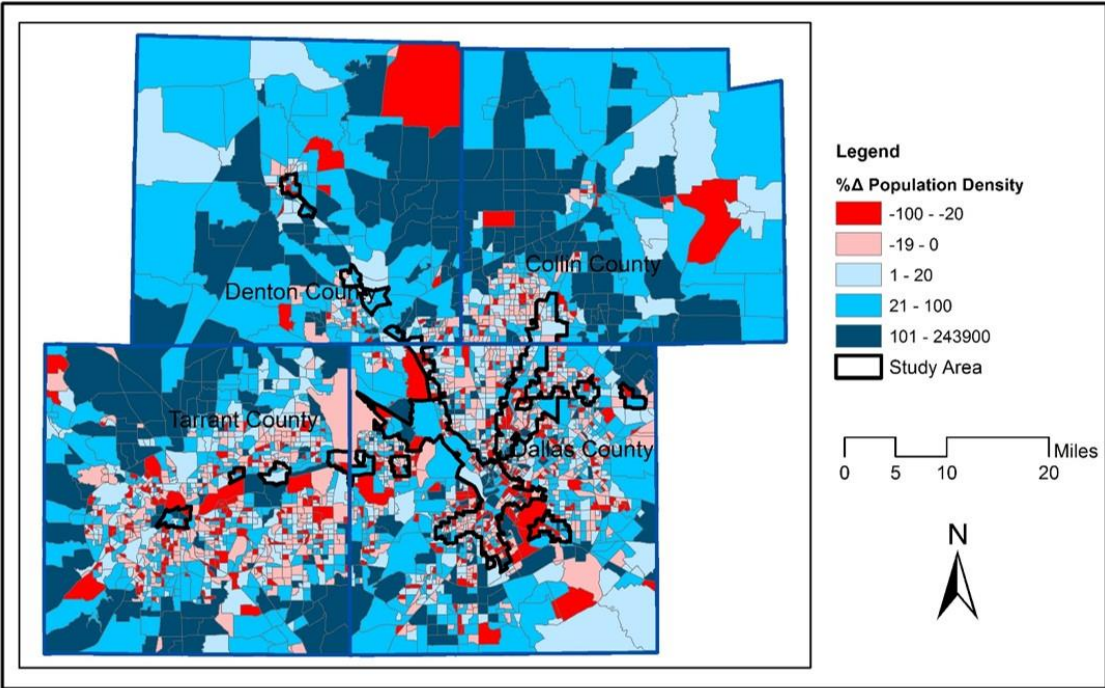
Figure 4-13 Percent change in population density between 2000 and 2014
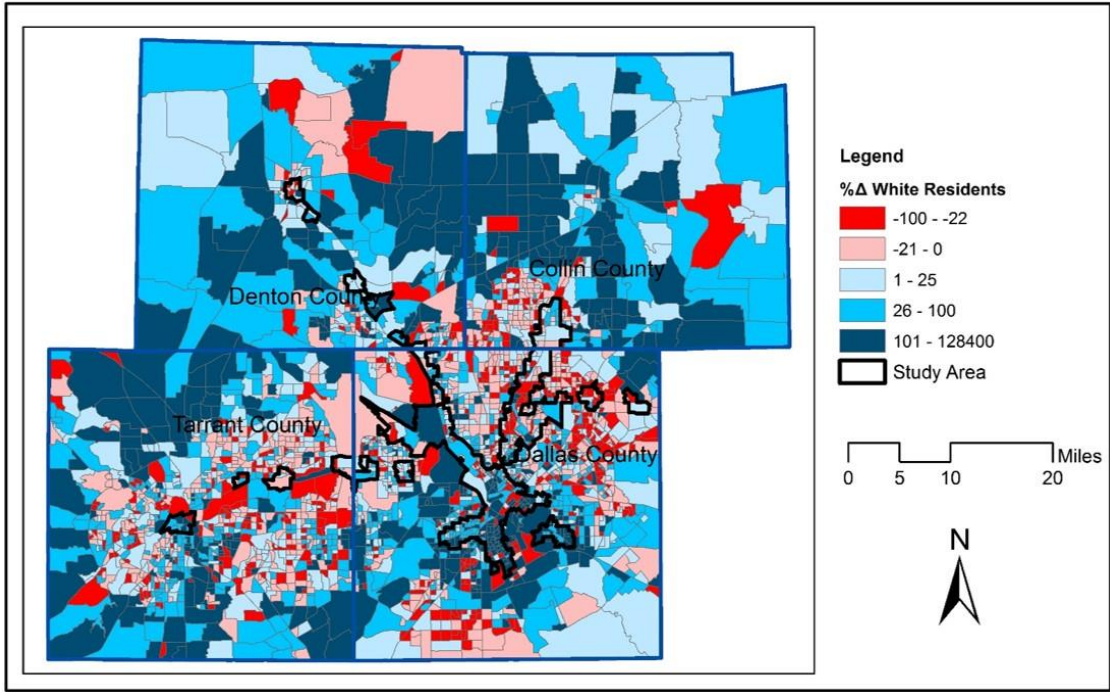
Figure 4-14 Percent change in white residents between 2000 and 2014
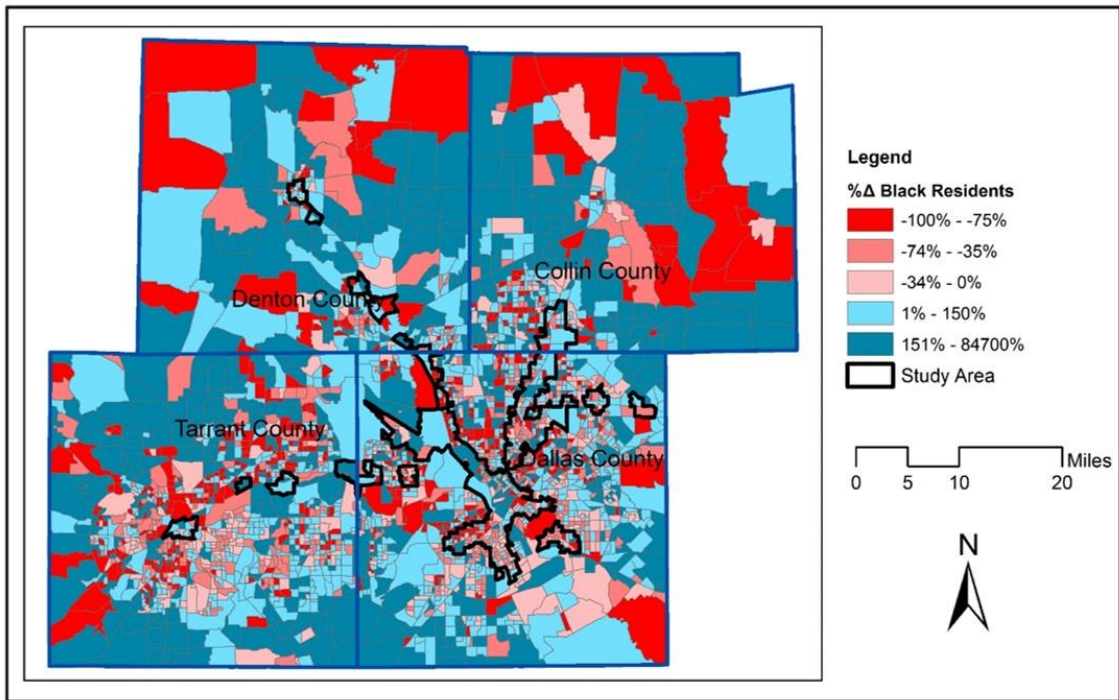
Figure 4-15 Percent change in black residents between 2000 and 2014
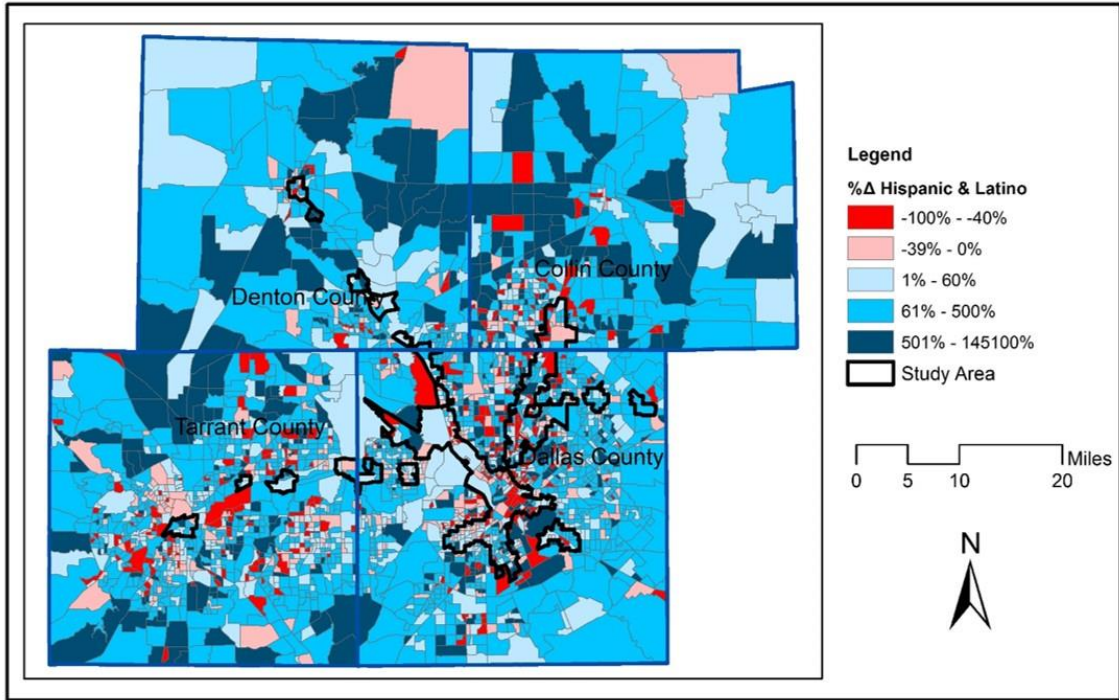
Figure 4-16 Percent change in Hispanic and Latino between 2000 and 2014
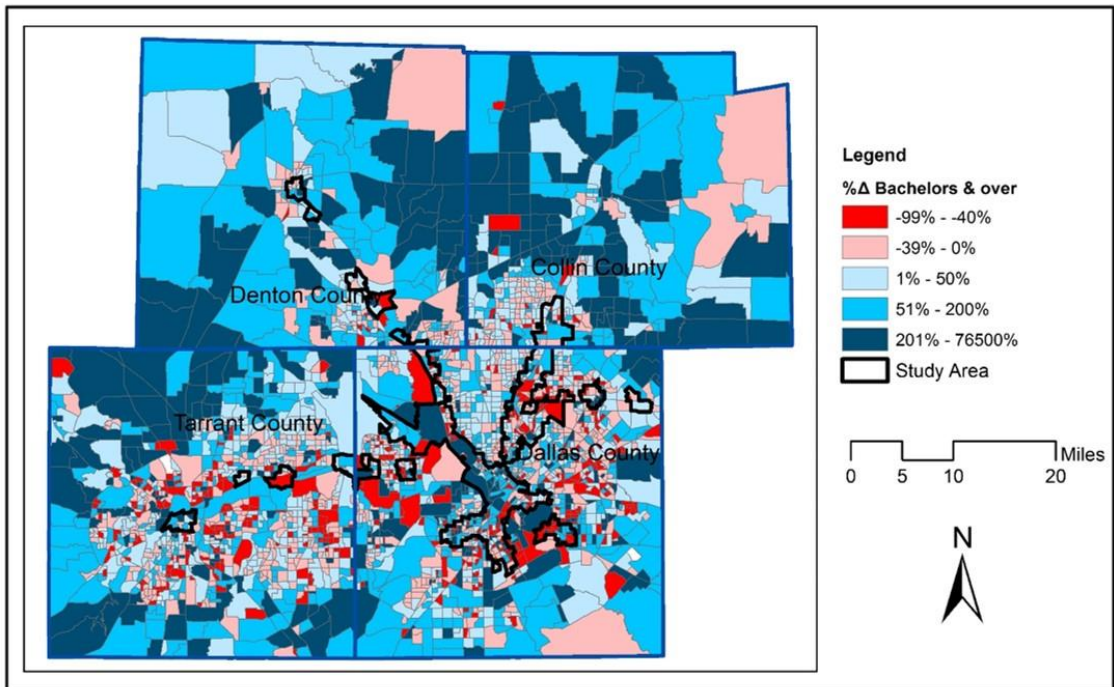
Figure 4-17 Percent change in residents with bachelor's degree and over between 2000 and 2014
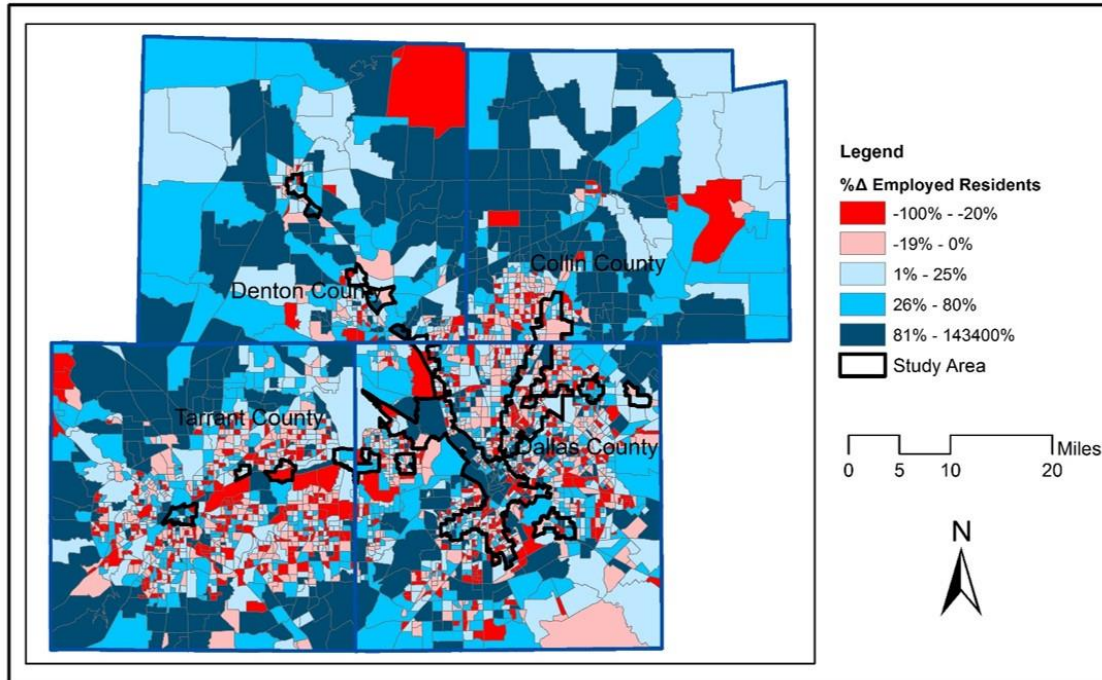
Figure 4-18 Percent change in employed residents between 2000 and 2014
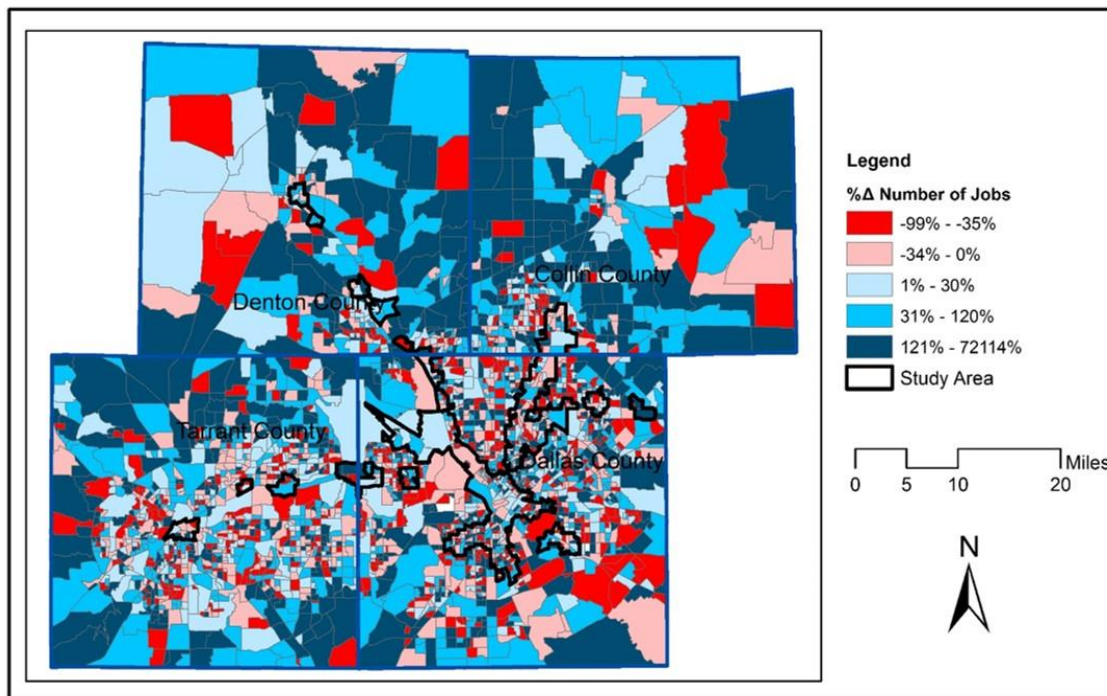
Figure 4-19 Percent change in number of jobs between 2002 and 2014
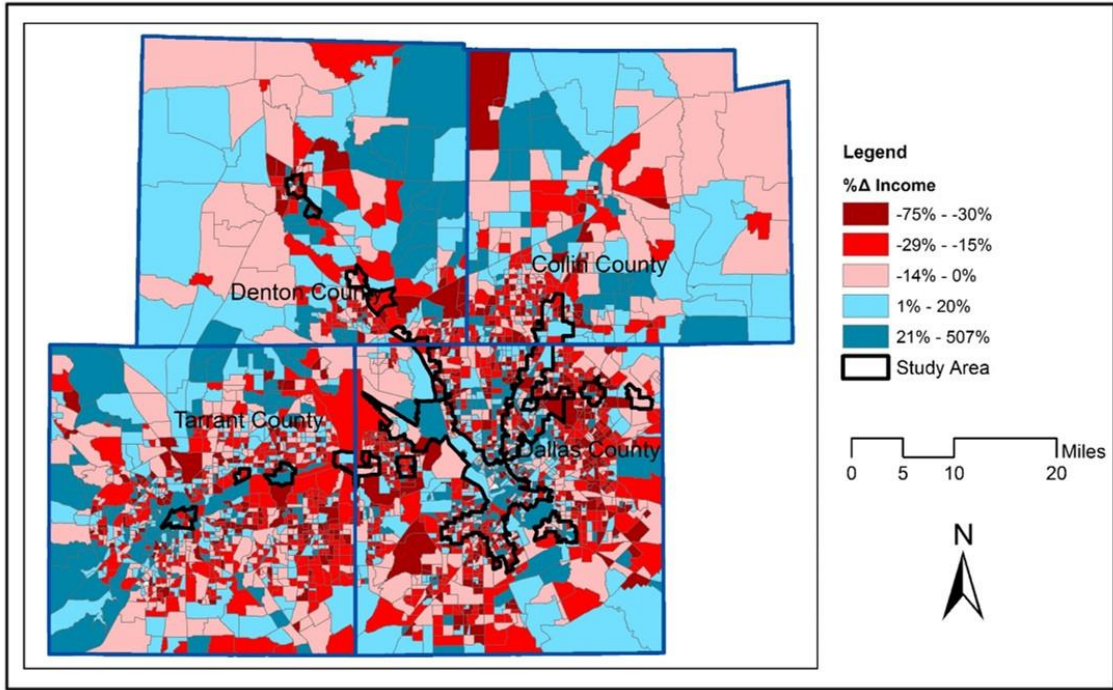
Figure 4-20 Percent change in residents income between 2000 and 2014
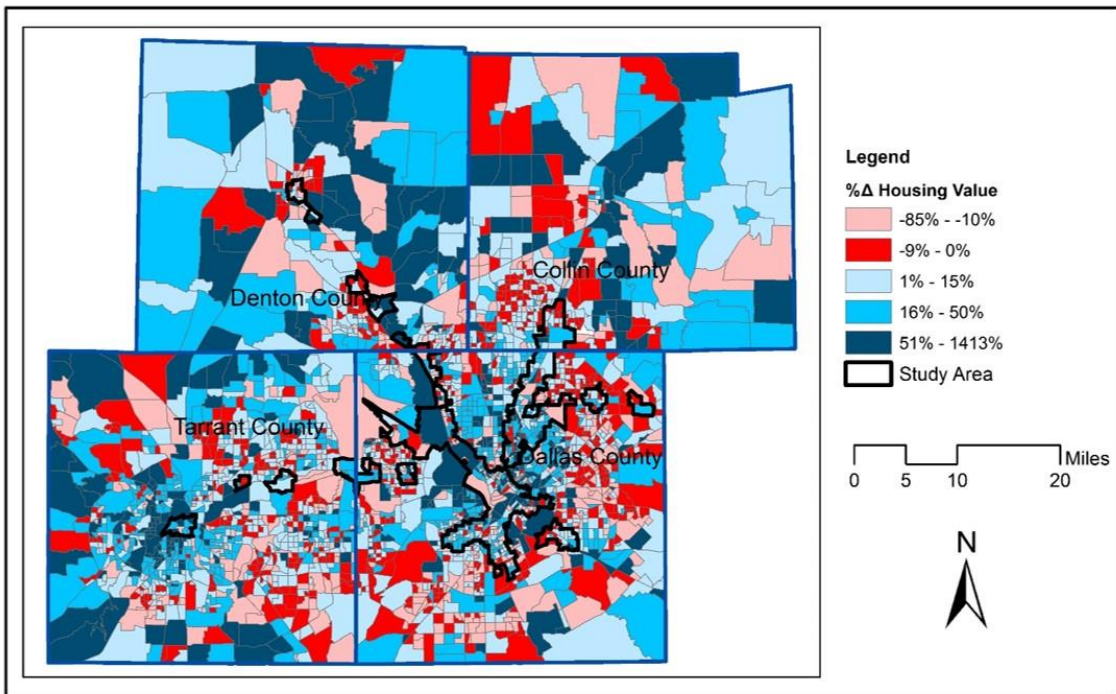
Figure 4-21 Percent change in housing value between 2000 and 2014

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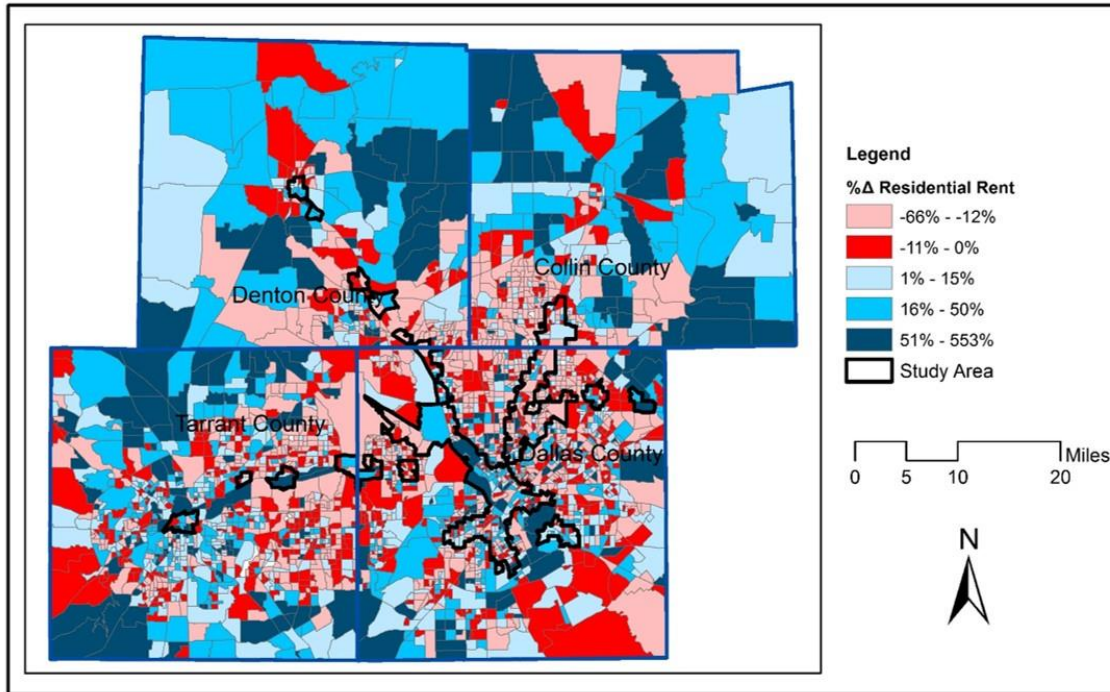
Figure 4-22 Percent change in median housing rent between 2000 and 2014

4.1.3   *Proximity to Rail Stations and other Important Points*

Variables related to proximity are measured as the straight-line distance from a rail station to the destination. In accordance with several social and economic theories and the literature review, one of the major factors that may affect the research questions (the dependent variables) is proximity to rail stations, but other proximity related variables also may have an effect on the dependent variables. These proximity related variables include: distance to the nearest highway access ramp, distance to nearest downtown, distance to the major employer, and distance to some amenities (e.g. school, shopping mall, and parks).

The major proximity variable is the straight-line or aerial distance from the centroid of selected block groups to the closest rail station within the DFW area. After computing the distances using ArcGIS, the shortest distance found between the centroid of a block group to the nearest rail station is 217 feet and the longest distance is 6,695 feet (≈1.27 mile); the median distance is 3,645 feet or 0.7 miles. Another proximity variable that may affect the dependent variables is the distance from the centroid of each selected block group to the closest highway access ramp. Based on the ArcGIS calculation of the distances to the nearest highway access ramp, the shortest distance is 20 feet from the centroid of one of

the block groups, and the longest distance is 13,149 feet (≈ 2.5 miles). The median of the distances to a highway ramp is 2,548 feet, which is roughly 0.5 miles.

Based on the NCTCOG database, there are seven downtowns either within or in proximity to the study area. The shortest distance between the centroid of the selected block groups and the closest downtown is 0.08 miles and the longest is 8.33 miles. In addition, measuring the straight-line distance from selected block group centroids to the closest major employers shows that the shortest distance is 115 feet and the longest distance is 9,774 feet (≈ 1.85 mile). The median of the distances between the centroid of block groups and the major employers is 2,704 feet (≈ 0.5 mile).

The distances to major amenities that may affect some of the research questions (dependent variables) also have been computed by ArcGIS. These amenities include schools, shopping malls, and parks. The NCTCOG database provides all of these data as shapefiles to be used by ArcGIS. Computing the distances from each block group centroid to the nearest school shows that the shortest distance is 111 feet, while the longest distance is 12,828 feet (≈ 2.5 miles). The median distance is 1,755 feet. The shortest distance to a shopping mall within the study area is 0.10 miles, while the longest distance was quite far from the study area, or around 8 miles. Finally, the distance between each block group to the closest centroid of a park located either within the study area or in proximity to study area is 113 feet and the longest distance is 7,169 feet (≈1.35 mile). The median distance is 1,862 feet. Table 4-4 shows all important proximity variables related to this study.

Table 4-4 Proximity related variables

Proximity variables for block groups	Minimum	Maximum	Mean	Median
Distance to nearest rail station (feet)	217	6,695	3,532	3,645
Distance to nearest highway access ramp (feet)	20	13,149	3,277	2,548
Distance to nearest downtown (mile)	0.08	8.33	3.82	3.87
Distance to closest major employers[4] (feet)	115	9,774	3,068	2,704
Distance to nearest school (feet)	111	12,828	2,016	1,755
Distance to nearest shopping mall (mile)	0.10	7.83	3.12	2.97
Distance to nearest park (feet)	113	7,169	2,139	1,862

4 In this study, the major employers including in the study area are the employment establishments that have 200 workers or more

Chapter 5

Regressions and Results

The previous chapter discussed the descriptive statistics of changes in many of the social, economic, spatial factors of the area surrounding rail stations and of the entirety of the four counties served by rail transit systems between 2000 and 2014. This chapter discusses some of the structured approaches to build an appropriate regression model and then presents the results of the best regression models. Building a model is a difficult process, and it requires prior knowledge of independent variables that are to be included in the model. Thus, Berenson's model building (Berenson et al., 2009) and Anjomani's version of model building (Anjomani, 2016) will be used to build the most appropriate regression models. Figure 5-1 shows the summary of Berenson's model building steps and Figure 5-2 summarizes the steps involved in Anjomani's version of the model building.
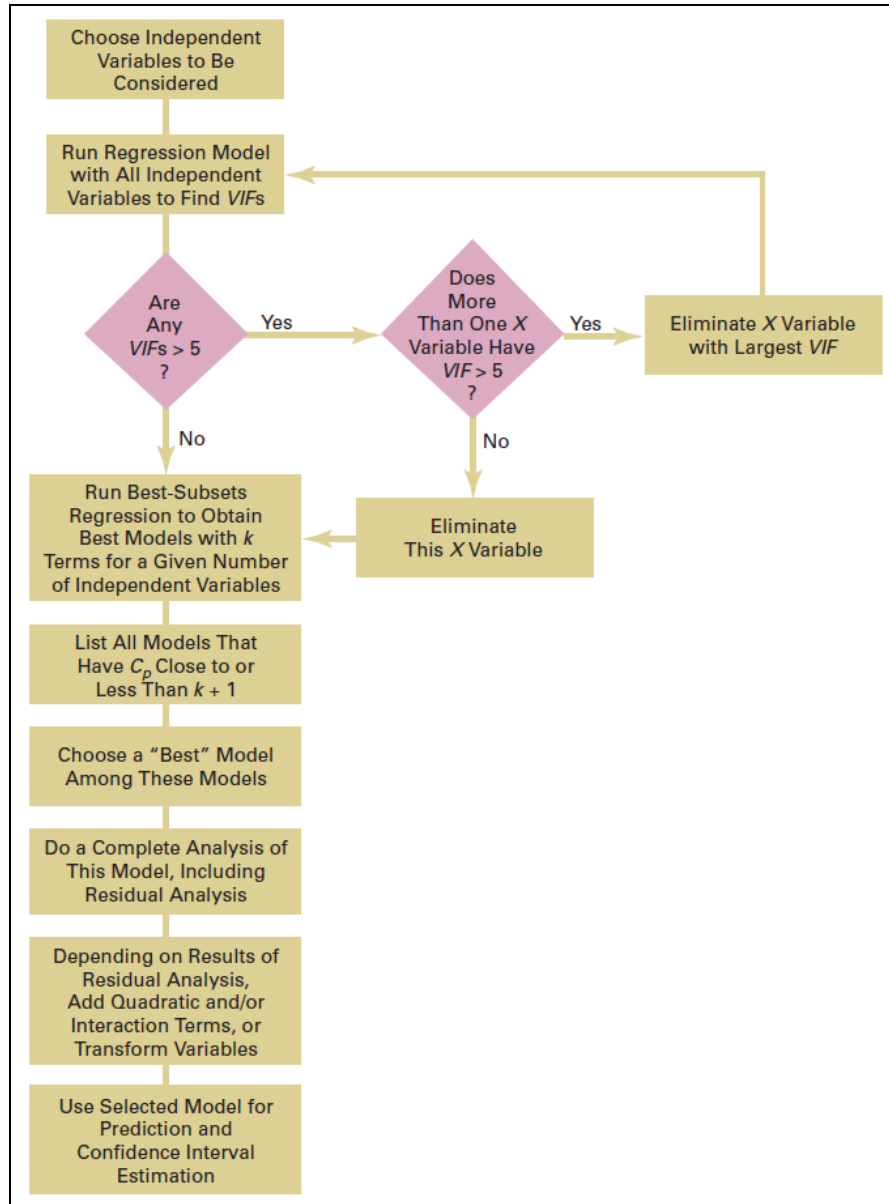
Figure 5-1 Berenson's model building steps
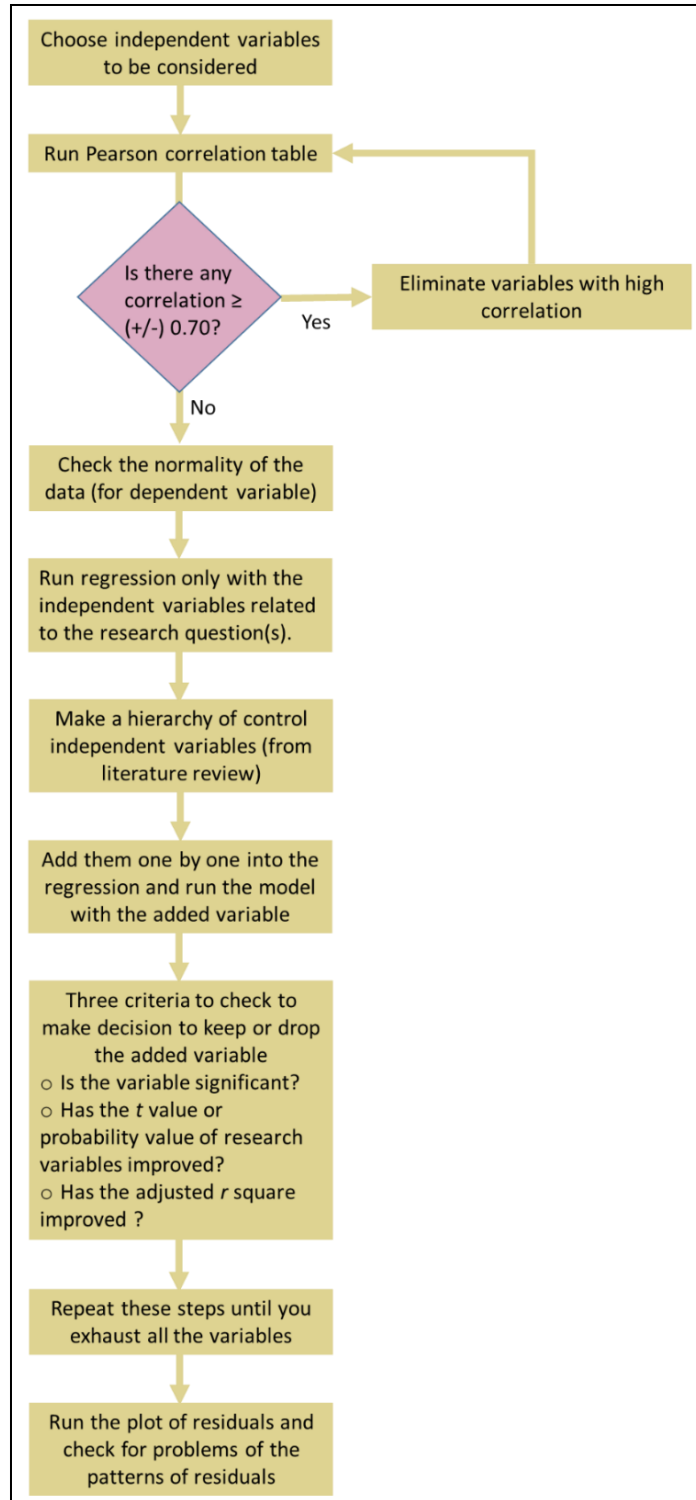
Figure 5-2 Anjomani's model building steps

5.1 Test of Normality

The assumption of normality should be checked for many of the statistical procedures to identify if the data are normally distributed or not (Ghasemi & Zahediasl, 2012). The test of normality should be taken for continuous dependent variables especially with variables that have many observations (Anjomani, 2016; Ghasemi & Zahediasl, 2012; Wooldridge, 2013). However, some scholars assert that there is no need for this test with large sample sizes (more than 40 observations) since the non-normal distribution of data does not cause a major problem (Altman & Bland, 1995; Elliott & Woodward, 2007; Field, 2009; Pallant, 2013). Normality tests can be done using several methods to assess whether the data is normally distributed, but the most used two techniques are graphical (e.g. histogram, Q-Q probability plots, and P-P of plot residual) and statistical (e.g. Kolmogorov-Smirnov and Shapiro-Wilk tests) (Thode, 2002). The null hypothesis for these two methods—which is the desired hypothesis of the researcher—is that the sample is normally distributed. This can be proven by testing the normality, as long as the significant value (P value) is above 0.05 (Field, 2009; Ghasemi & Zahediasl, 2012; Thode, 2002).

Using SPSS to test the normality shows that the probability or significant of the initial dependent variables (%ΔHousvalue, %ΔWhite, and %ΔPopDen or ΔHousvalue, ΔWhite, and ΔPopDen) are significant, meaning the data is not normally distributed. In addition, the results of the residual analysis do not show a normal distribution either within the histogram, Q-Q plot, or P-P plot. Therefore, a transformation of data has been used to achieve the normality of variables. I have tried many transformation methods such as square root, square, and reciprocal, but finally, I used the most popular transformation method – the natural logarithm (Wooldridge, 2013). This transformation lets us accept the null hypotheses, which indicates a normal distribution of the data. However, in this study, there are not just positive changes, but also negative and zero changes in some factors between 2000 and 2014, and the logarithm cannot be used with negative and zero values. Therefore, a conventional technique to handle zero value is to add a constant value, preferably to 1, and then square the result to deal with a

negative value; this can be written as $Ln(\Delta x+1)^2$. All variables pertaining to distances do not have negative or zero values, so only the natural logarithm will be used,[5] which can be written as $Ln(x)$.

Table 5-1 shows the statistical method of testing the normality, and it describes the SPSS outputs that show the probability of dependent variables as greater than 0.05, which means the null hypotheses cannot be rejected and the data is normally distributed.

Table 5-1 Test of normality for the selected dependent variables

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
LnΔHousvalue	.021	454	.200[*]	.996	454	.333
LnΔWhite	.063	454	.054	.982	454	.102
LnΔPopDen	.041	454	.071	.995	454	.103

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

The Q-Q probability plots should show that data falls along the line, which means a normal distribution, whereas the frequency distribution (histogram) is usually utilized to check normality visually by showing a bell curve (Field, 2009). Figure 5-3 shows that in all of the charts, the histograms show a bell-shape; the Q-Q plot also indicates that all data points fall very close to the diagonal line. Woolridge (2013) stated that population error (u), or the residual, should be also normally distributed and it should be independent from the explanatory variables. Thus, the test of normality should be done for the residuals errors. The SPSS can compute the normality test of residuals using a histogram and P-P plot of standardized residuals (zresid residuals) as shown in Figure 5-4. The histogram should form a bell shape and the P-P plots should be linear with all the data points along the diagonal line; if the points begin curving away from the line, the error term is not normally distributed. The results in Figure 5-4 indicate that residuals are normally distributed.

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5 Both *Ln (Δx+1)²* and *Ln (x)* henceforth in tables and figures will be written as *LnΔx* or *Lnx*
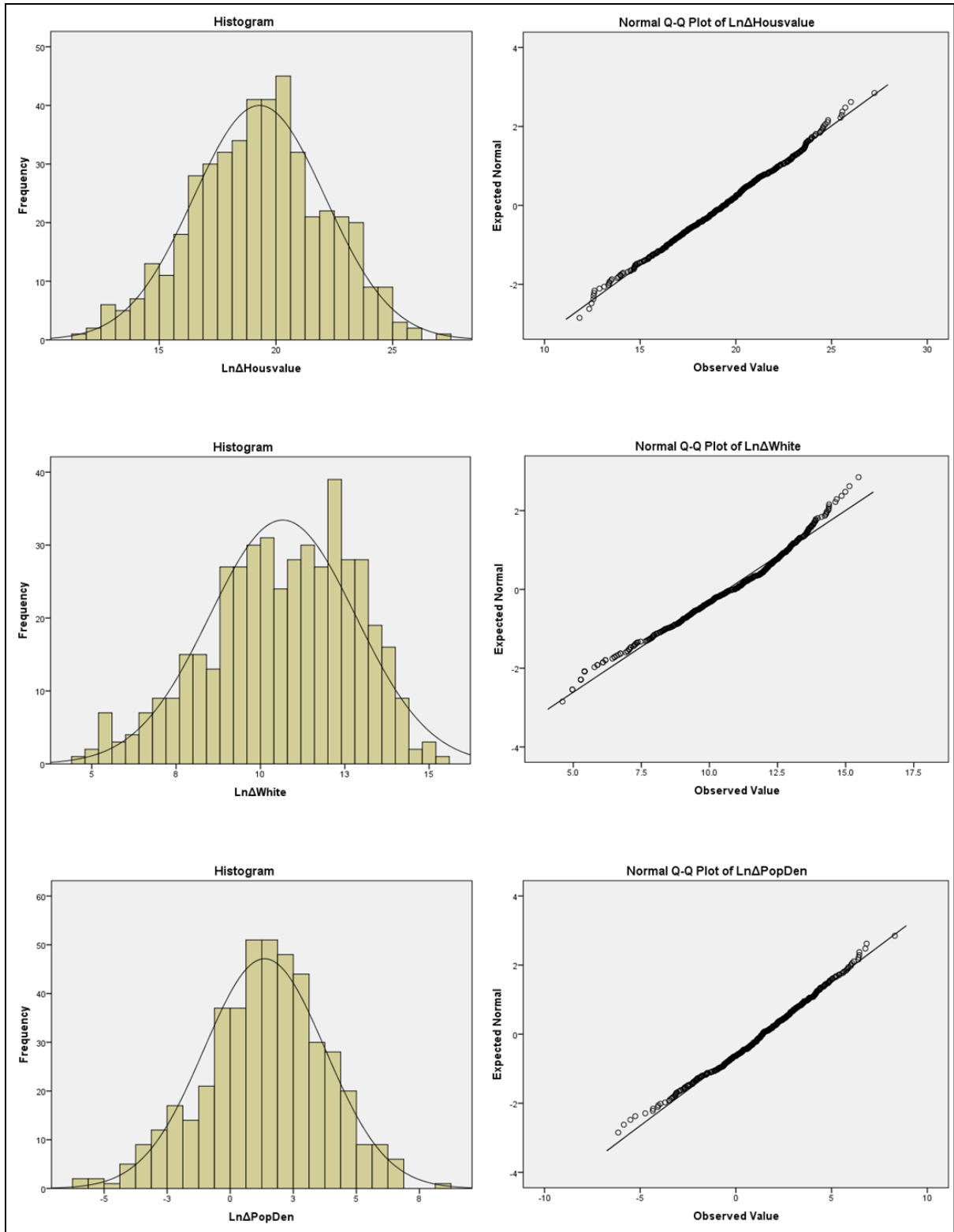
Figure 5-3 Histograms (left) and Q-Q plots (right) of the selected dependent variables
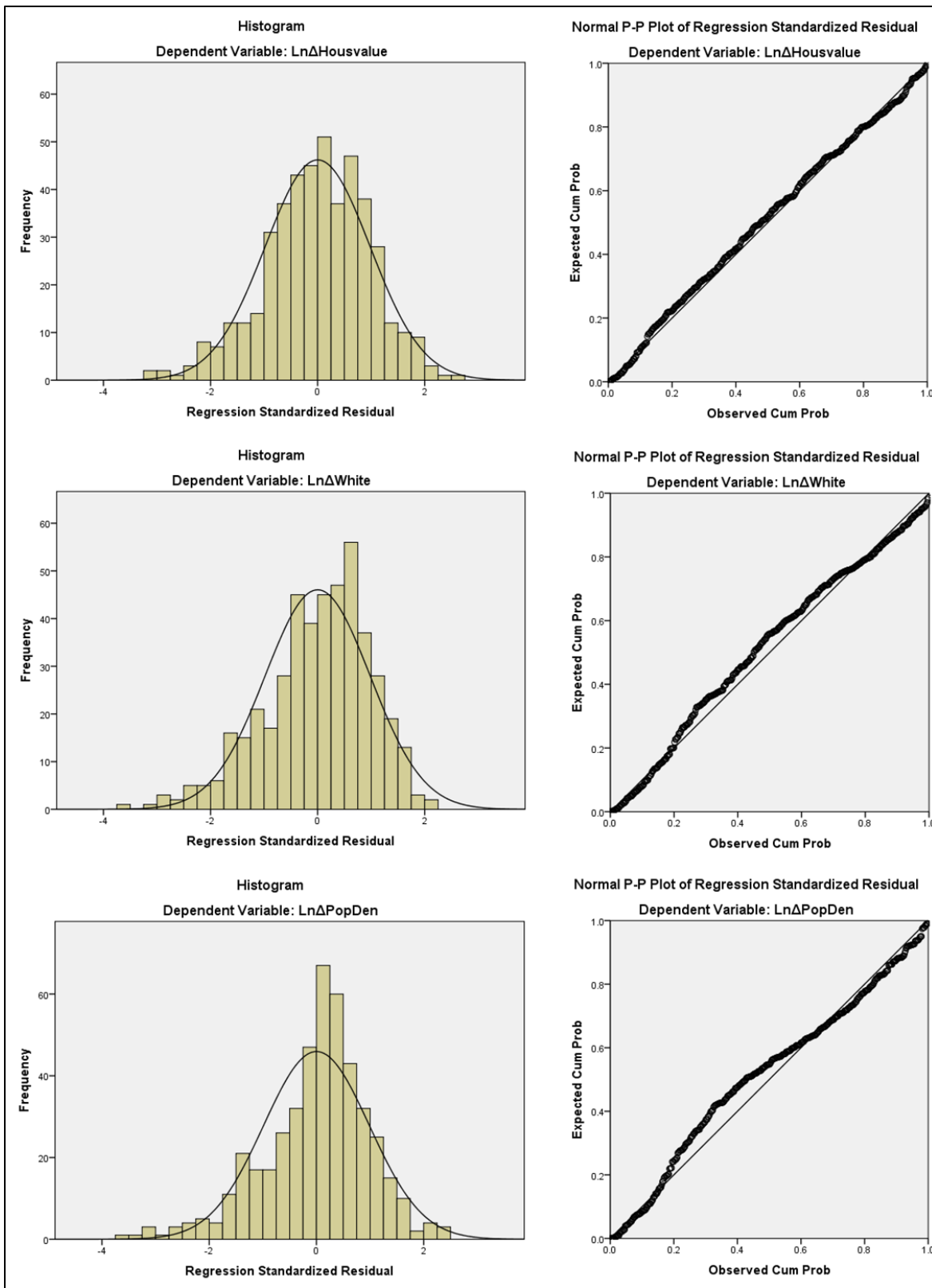
Figure 5-4 Histograms (left) and P-P plots (right) of the selected dependent variables

5.2 Test of Multicollinearity

5.2.1   *Testing for Variance Inflation Factor (VIF) for the Models*

The first step of Berenson's model building is to measure the amount of collinearity between two or more independent variables, which is called variance inflation factor (VIF) (Berenson et al., 2009). The equation below shows the variance inflation factor for variable i:

$$VIF_i = \frac{1}{1 - R_i^2} \tag{5-1}$$

To compute VIF_i, the coefficient of multiple determination for a regression model R_i^2 should be calculated by considering X_i as the dependent variable and the rest of the X variables as independent variables (Berenson et al., 2009). If the VIF is greater than 5.0, the multicollinearity is excessively high, meaning a severe correlation across the independent variables (Berenson et al., 2009; Snee, 1973; Studenmund, 2006). However, the smaller the value of VIF, the lower the possibility of correlations between explanatory variables; when any VIF equals one, the independent variables are not correlated (Berenson et al., 2009).

In addition, VIF is the reciprocal of tolerance, and SPSS can help to calculate the tolerance and VIF. After calculating VIF as shown in Table 5-2, Table 5-3, and Table 5-4, all models are free of collinearity problems. The tables below show the summary results of the computations of VIF for all models related to this study. The results indicate that each independent variable has a VIF value that is less than 5.0. As all values range between 1.062 and 1.643, this means a lower correlation between the independent variables. Thus, each variable can contribute to its model as an explanatory variable in estimating the dependent variable.

Table 5-2 Variance inflation factors (VIF) for Equation 1: LnΔHousvalue (2000-2014)

Independent Variables	Tolerance	VIF
LnDis2station	.930	1.075
LnDis2hgy	.810	1.235
LnDis2Down	.623	1.606
Dum_TOD	.743	1.346
LnΔIncome	.900	1.111
LnΔBlk	.906	1.104
LnΔHisp	.765	1.308
LnΔPopDen	.688	1.453
LnΔJob	.741	1.349
LnDis2Park	.801	1.248
LnDis2School	.831	1.204
Dum_RidPark	.777	1.287
LnΔCollege	.734	1.363
LnΔEmplyed	.763	1.310
LnDis2Mall	.609	1.643

Table 5-3 Variance inflation factors (VIF) for Equation 2: LnΔWhite (2000-2014)

Independent Variables	Tolerance	VIF
LnDis2station	.942	1.062
LnΔPopDen	.704	1.420
LnDis2Down	.758	1.319
LnΔCollege	.716	1.397
LnΔEmplyed	.784	1.276
LnΔIncome	.875	1.143
LnΔHousvalue	.745	1.342
LnΔHisp	.813	1.230
Dum_TOD	.806	1.241
LnΔRent	.877	1.141
LnDis2hgy	.834	1.199
LnΔJob	.744	1.344

Table 5-4 Variance inflation factors (VIF) for Equation 3: LnΔPopDen (2000-2014)

Independent Variables	Tolerance	VIF
LnDis2station	.935	1.069
LnDis2Down	.833	1.201
Dum_TOD	.851	1.176
LnΔHousvalue	.782	1.278
LnDis2hgy	.791	1.265
LnΔEmplyed	.773	1.294
Dum_RidPark	.868	1.152
LnΔPoverty	.879	1.138
LnΔIncome	.937	1.067
LnDis2MajEmplo	.665	1.503
LnΔWhite	.717	1.394
LnΔHisp	.830	1.205
LnΔJob	.675	1.482

5.2.2   *Pearson Correlation*

Another way of measuring the multicollinearity is running a Pearson correlation table. Pearson correlation coefficients (r) for changes in variables can help to measure the correlation and relationship between all variables before running the regression model (Achen, 1982). If variables have a high observed correlation, ranging between +0.70 to 1.00 or -0.70 to -1.00, this can be a danger level. If so, these variables should be eliminated from the model or the research should do some treatment on them (Clark & Hosking, 1986). In this study, none of the regression models has multicollinearity problem. In Table 5-5, the Pearson correlation coefficients of Equation 1 ranges from -0.346 to 0.383, which means a moderate relationship exists between the variables. Table 5-6 shows the Pearson correlation coefficients of Equation 2. The highest negative correlation is -0.288 and the highest positive correlation is 0.398. This means the variables are free of multicollinearity. Table 5-7 shows the Pearson correlation coefficients of Equation 3. The coefficients range from -0.485 to 0.398. Therefore, a problem of multicollinearity does not exist.

Table 5-5 Matrix of Pearson correlation coefficients of Equation 1: LnΔHousvalue (2000-2014)

Correlations															
	LnΔHousvalue	LnDis2station	LnDis2hgy	LnDis2Down	LnΔIncome	LnΔCollege	LnΔEmplyed	LnΔBlk	LnΔHisp	LnΔPopDen	LnΔJob	Dum_TOD	Dum_RidPark	LnDis2School	LnDis2Park	LnDis2Mall
LnΔHousvalue	1	.010	-.234**	.058	.192**	.353**	.022	-.064	-.022	.118*	.255**	.288**	-.129**	.118*	.035	-.346**
LnDis2station	.010	1	.122**	.046	.019	-.070	-.107*	-.044	.077	.011	-.111*	-.084	.106*	-.034	.110*	.066
LnDis2hgy	-.234**	.122**	1	.108*	-.054	-.191**	-.140**	-.037	.043	-.096*	-.312**	-.159**	.188**	-.114*	-.005	.235**
LnDis2Down	.058	.046	.108*	1	-.080	-.047	-.076	.124**	-.045	.001	-.227**	.139**	.146**	.128**	.323**	.238**
LnΔIncome	.192**	.019	-.054	-.080	1	.211**	-.066	-.095*	-.041	.003	.028	.121**	-.066	.035	-.020	-.231**
LnΔCollege	.353**	-.070	-.191**	-.047	.211**	1	.240**	-.011	-.051	.181**	.295**	.178**	-.047	.161**	.092*	-.333**
LnΔEmplyed	.022	-.107*	-.140**	-.076	-.066	.240**	1	.180**	.166**	.344**	.219**	-.006	-.098*	.046	-.011	-.100*
LnΔBlk	-.064	-.044	-.037	.124**	-.095*	-.011	.180**	1	.123**	.095*	.057	.001	.052	-.005	.018	.116*
LnΔHisp	-.022	.077	.043	-.045	-.041	-.051	.166**	.123**	1	.383**	-.015	-.062	.166**	-.015	-.020	.118*
LnΔPopDen	.118*	.011	-.096*	.001	.003	.181**	.344**	.095*	.383**	1	.025	.160**	-.061	-.086	-.058	-.128**
LnΔJob	.255**	-.111*	-.312**	-.227**	.028	.295**	.219**	.057	-.015	.025	1	.060	-.039	.072	.071	-.281**
Dum_TOD	.288**	-.084	-.159**	.139**	.121**	.178**	-.006	.001	-.062	.160**	.060	1	-.185**	-.042	.021	-.372**
Dum_RidPark	-.129**	.106*	.188**	.146**	-.066	-.047	-.098*	.052	.166**	-.061	-.039	-.185**	1	.179**	.234**	.257**
LnDis2Schol	.118*	-.034	-.114*	.128**	.035	.161**	.046	-.005	-.015	-.086	.072	-.042	.179**	1	.211**	-.045
LnDis2Park	.035	.110*	-.005	.323**	-.020	.092*	-.011	.018	-.020	-.058	.071	.021	.234**	.211**	1	.034
LnDis2Mall	-.346**	.066	.235**	.238**	-.231**	-.333**	-.100*	.116*	.118*	-.128**	-.281**	-.372**	.257**	-.045	.034	1

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

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

Table 5-6 Matrix of Pearson correlation coefficients of Equation 2: LnΔWhite (2000-2014)

Correlations													
	LnΔWhite	LnDis2station	LnDis2hgy	LnDis2Down	LnΔIncome	LnΔCollege	LnΔEmplyed	LnΔHisp	LnΔHousvalue	LnΔRent	LnΔPopDen	LnΔJob	Dum_TOD
LnΔWhite	1	-.119*	.007	.092	-.083	.203**	.398**	.288**	-.010	-.051	.337**	.171**	-.011
LnDis2station	-.119*	1	.122**	.046	.019	-.070	-.107*	.077	.010	-.034	.011	-.111*	-.084
LnDis2hgy	.007	.122**	1	.108*	-.054	-.191**	-.140**	.043	-.234**	-.072	-.096*	-.312**	-.159**
LnDis2Down	.092	.046	.108*	1	-.080	-.047	-.076	-.045	.058	.085	.001	-.227**	.139**
LnΔIncome	-.083	.019	-.054	-.080	1	.211**	-.066	-.041	.192**	.237**	.003	.028	.121**
LnΔCollege	.203**	-.070	-.191**	-.047	.211**	1	.240**	-.051	.353**	.260**	.181**	.295**	.178**
LnΔEmplyed	.398**	-.107*	-.140**	-.076	-.066	.240**	1	.166**	.022	.008	.344**	.219**	-.006
LnΔHisp	.288**	.077	.043	-.045	-.041	-.051	.166**	1	-.022	-.040	.383**	-.015	-.062
LnΔHousvalue	-.010	.010	-.234**	.058	.192**	.353**	.022	-.022	1	.157**	.118*	.255**	.288**
LnΔRent	-.051	-.034	-.072	.085	.237**	.260**	.008	-.040	.157**	1	.002	.097*	.085
LnΔPopDen	.337**	.011	-.096*	.001	.003	.181**	.344**	.383**	.118*	.002	1	.025	.160**
LnΔJob	.171**	-.111*	-.312**	-.227**	.028	.295**	.219**	-.015	.255**	.097*	.025	1	.060
Dum_TOD	-.011	-.084	-.159**	.139**	.121**	.178**	-.006	-.062	.288**	.085	.160**	.060	1
**. Correlation is significant at the 0.01 level (2-tailed).													
*. Correlation is significant at the 0.05 level (2-tailed).													

Table 5-7 Matrix of Pearson correlation coefficients of Equation 3: LnΔPopDen (2000-2014)

Correlations	LnΔPopDen	LnDis2station	LnDis2hgy	LnDis2Down	LnDis2MajEmplo	LnΔIncome	LnΔEmplyed	LnΔWhite	LnΔHisp	LnΔPoverty	LnΔHousvalue	LnΔJob	Dum_TOD	Dum_RidPark
LnΔPopDen	1	.011	-.096*	.001	-.125**	.003	.344**	.337**	.383**	.243**	.118*	.025	.160**	-.061
LnDis2station	.011	1	.122**	.046	.142**	.019	-.107*	-.119*	.077	-.018	.010	-.111*	-.084	.106*
LnDis2hgy	-.096*	.122**	1	.108*	.373**	-.054	-.140**	.007	.043	-.048	-.234**	-.312**	-.159**	.188**
LnDis2Down	.001	.046	.108*	1	.202**	-.080	-.076	.092	-.045	.018	.058	-.227**	.139**	.146**
LnDis2MajEmplo	-.125**	.142**	.373**	.202**	1	-.081	-.224**	-.087	.026	-.064	-.274**	-.485**	-.129**	.125**
LnΔIncome	.003	.019	-.054	-.080	-.081	1	-.066	-.083	-.041	-.011	.192**	.028	.121**	-.066
LnΔEmplyed	.344**	-.107*	-.140**	-.076	-.224**	-.066	1	.398**	.166**	.169**	.022	.219**	-.006	-.098*
LnΔWhite	.337**	-.119*	.007	.092	-.087	-.083	.398**	1	.288**	.270**	-.010	.171**	-.011	.044
LnΔHisp	.383**	.077	.043	-.045	.026	-.041	.166**	.288**	1	.256**	-.022	-.015	-.062	.166**
LnΔPoverty	.243**	-.018	-.048	.018	-.064	-.011	.169**	.270**	.256**	1	-.042	.039	.031	.041
LnΔHousvalue	.118*	.010	-.234**	.058	-.274**	.192**	.022	-.010	-.022	-.042	1	.255**	.288**	-.129**
LnΔJob	.025	-.111*	-.312**	-.227**	-.485**	.028	.219**	.171**	-.015	.039	.255**	1	.060	-.039
Dum_TOD	.160**	-.084	-.159**	.139**	-.129**	.121**	-.006	-.011	-.062	.031	.288**	.060	1	-.185**
Dum_RidPark	-.061	.106*	.188**	.146**	.125**	-.066	-.098*	.044	.166**	.041	-.129**	-.039	-.185**	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

5.3 Test of Homoscedasticity

The residual plot should be distributed randomly throughout the range of dependent variables. The variance of errors should be constant, equally distributed, and without a specific pattern. In other words, if the scatterplot is random, the relationship between the variables are linear (Berenson et al., 2009). Funnel, fanned, or curved patterns indicate a problem of heteroscedasticity, which means that the error term is not constant and the homoscedasticity assumption is violated. In this situation, if the linear regression does not properly fit the data, the researcher can try a non-linear regression. This assumption can be carried out in SPSS and checked by a visual examination of a plot of the regression standardized predicted Z value on the X-axis and the regression standardized residual on the Y-axis (Osborne & Waters, 2002; Tabachnick & Fidell, 2007). Figure 5-5, Figure 5-6, and Figure 5-7 show that the variance of errors is approximately constant, meaning the scatterplots are distributed randomly and the relationship between variables in the three models are linear.
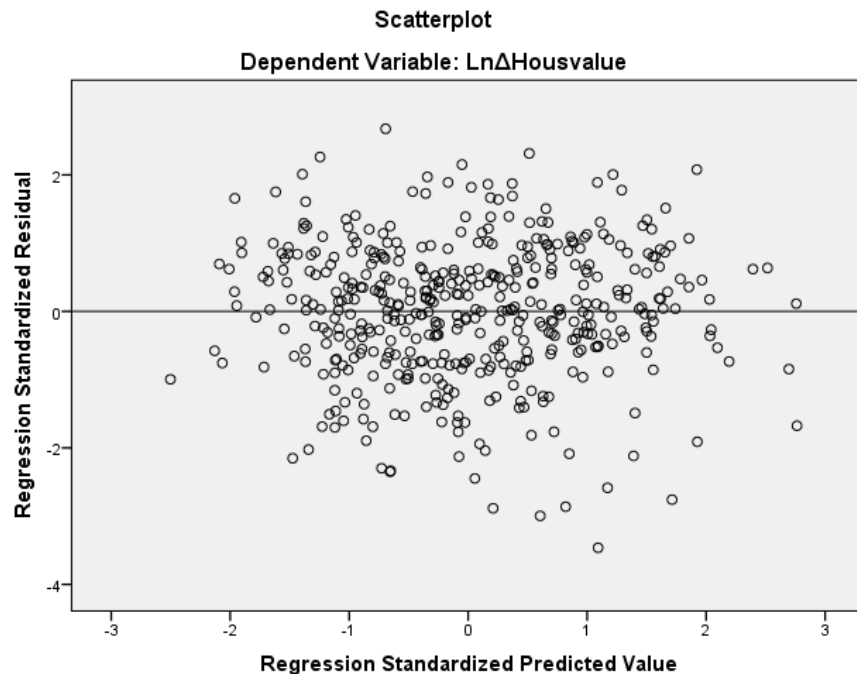
Figure 5-5 Residual plot for Equation 1: LnΔHousvalue (2000-2014)

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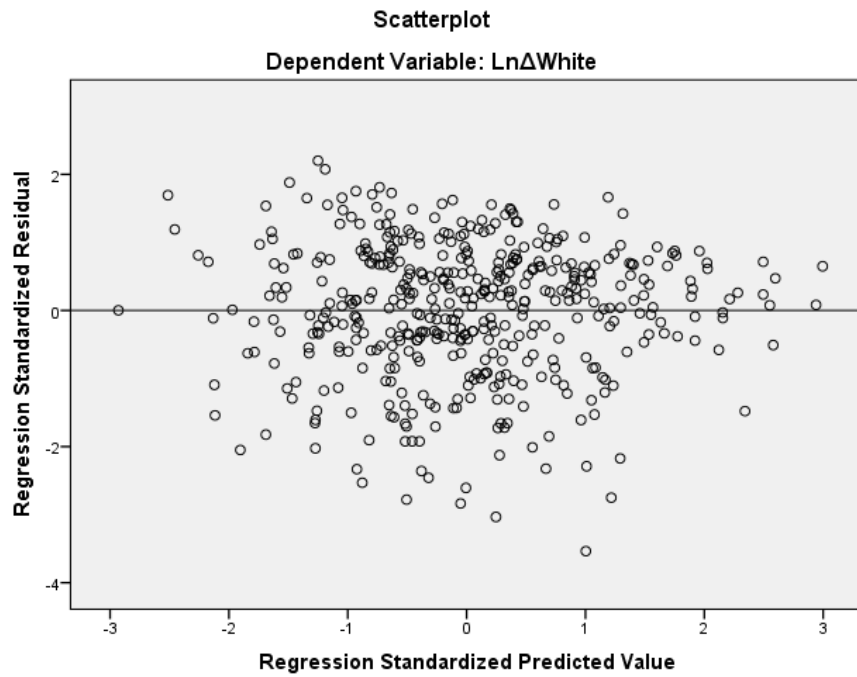
Figure 5-6 Residual plot for Equation 2: LnΔWhite (2000-2014)
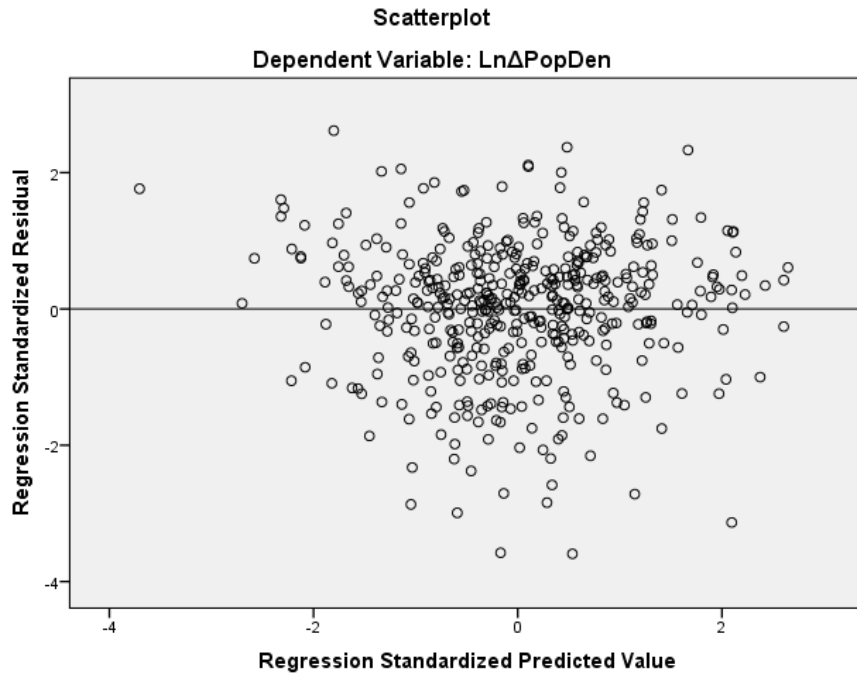
Figure 5-7 Residual plot for Equation 3: LnΔPopDen (2000-2014)

5.4 Selection of Multiple Regression Models

Regression model building can assist in determining which factors most heavily affect the dependent variable, and therefore, choosing the best model without considering all possible models (Berenson et al., 2009). After testing the normality, multicollinearity, and homoscedasticity, two approaches will be combined to evaluate all possible models for the remaining independent variables and to make the most informed choice. The first approach is based on Berenson et al. (2009). The best-subsets regression identifies all of the possible regression models derived from the set of the independent variables. In this approach, two criterions determine the best model. They are the higher adjusted R^2 and the Cp statistic that is close to or less than the number of independent variables plus one (K+1) (Berenson et al., 2009). The Cp statistic measures the variation between the regression model with only the selected independent variables and the full regression model that has all independent variables (Berenson et al., 2009). The second approach is based on Anjomani's (2016) model building, in which the researcher should run the regression model with only the independent variables related to the research questions first and then make a hierarchy of independent variables from the literature review. After that, the researcher should add those independent variables, one by one, into the regression and run the model with the added variable (Anjomani, 2016). Anjomani mentioned three criteria to decide whether to keep or drop the added independent variable, including the significance of the variable, the improvement of t-value, and the improvement of adjusted R^2.

For this study, first, I ran the regression model with only the independent variables related to the research questions, and then added the rest of the independent variables, one by one, until exhausting all the variables. The best model will be determined based on the improvement of t-value, adjusted R^2, the significance of the added independent variable, and the Cp statistic.

In this study, all variables (either dependent or independent) that experienced change between 2000 and 2014 will appear in a logarithmic form. The main reasons behind this are to get a distribution that is fairly normal, to narrow the range of variables, and to impose a constant percentage of the independent variables on the dependent variable—since the changes in an original variable may not be

reasonable (Wooldridge, 2013). Additionally, using the natural logarithm is important to get the constant elasticity model. If the dependent and independent variables appear in the logarithmic form, this model is called the log-log or double log model. In this model, the coefficient (β) is the elasticity of the dependent variable with respect to the independent variable, which means (1%Δx = β %Δy) (Wooldridge, 2013).

The other functional form involving logarithms in this study is the log-level model, which is also called semi-log or semi-elasticity (Wooldridge, 2013). In the log-level model, the dependent variable appears in the logarithmic form, while the independent variables stay in the original form. In this case, the coefficients of the independent variables have a percentage explanation when it is multiplied by 100, which means (Δx = (100*β) %Δy) (Wooldridge, 2013). This type of model will be used in this study for dummy variables. The major drawback of using the logarithmic form for the dependent variable is the difficulty in predicting the original value of the dependent variable. In addition, block groups within the study area between 2000 and 2014 experienced increases and decreases, and some of the block groups did not experience any change in the variables that will be examined. As mentioned earlier, the logarithm of zero and a negative value is not defined, so $Ln(x)$ and $Ln(\Delta x+1)^2$ will be used, but it is sometimes difficult to interpret the coefficients in this situation, as explained by Wooldridge (2013).

5.5 Procedures and Analysis

The multiple regression models were conducted using SPSS to examine the impact of different independent variables on the dependent variables within the block groups surrounding transit rail stations in the DFW area. As was discussed in the literature review, the models were built by including most factors that determine the changes in dependent variables and have been mentioned in various theories and empirical studies. Before running the regression, this study conducted a series of data transformation and coding. The first transformation was to transform the 2014 values of housing value, rent, and residents' income, to 2000 dollars. Then, the researcher computed the changes between 2000 and 2014 for each block group within the study area. After that, all variables that experienced changes between 2000 and 2014 were transformed to $Ln(\Delta x+1)^2$ since the regression models were in log-log or log-level forms and the variables had positive, negative, and zero values. Variables related to distance were

transformed to Ln(x) because all distances were positive values, and dummy variables were kept with their original values.

Two points are worth mentioning at the outset. First, as was discussed before, the regression models for this study are in the log-log (double log) form and, as such, the coefficients will constitute the elasticities. Next, except for distances and the dummy variables, all the variables measured differences between 2000 and 2014. Therefore, an interpretation of their coefficients as elasticities indicates a percent increase in the change of the explanatory variables between 2000 and 2014 will lead to a percent change for the coefficient of changes in the dependent variable between 2000 and 2014. To keep the interpretations simple and avoid confusion, the "change" from the name of the variables will not be used.

5.5.1   Regression Analysis and Results for Research Question 1: Change in Housing Value (2000-2014) Due to Proximity to Rail Stations

The first regression model estimates the changes in housing value between 2000 and 2014 as a function of proximity to rail stations in the DFW area and other controlling factors such as social, economic, and spatial factors. The final model is formulated to examine the impact of proximity to rail transit stations on housing values as follows:

$$Ln(\Delta Housvalue+1)^2 = \alpha + \beta_1 (Dis2station) + \beta_2 (Dis2hgy) + \beta_3 (Dis2Down) + \beta_4$$
$$Ln(\Delta Income+1)^2 + \beta_5 Ln(\Delta College+1)^2 + \beta_6 Ln(\Delta Emplyed+1)^2 + \beta_7 Ln(\Delta Blk+1)^2 +$$
$$\beta_8 Ln(\Delta Hisp+1)^2 + \beta_9 Ln(\Delta PopDen+1)^2 + \beta_{10} Ln(\Delta Job+1)^2 + \beta_{11} (Dum\_TOD) + \beta_{12} \tag{5-2}$$
$$(Dum\_RidPark) + \beta_{13} (Dis2School) + \beta_{14} (Dis2Park) + \beta_{15} (Dis2Mall)$$

As was discussed in model building process, the regression model will be run first with only the independent variables that directly relate to the research question. The major factors that are expected to have the largest contribution to explaining housing prices next to rail stations are based on theories and the empirical studies. Those variables include: distance to rail station, distance to highway ramp, distance to closest downtown, TOD development, income of residents, and change in number of black residents. Then, the independent variables will be added, one by one, based on their importance and common

usage in the literature to the regression model until all the variables are exhausted. Table 5-5 shows the regression equations that will be run to find the best model. In the initial formulation of the regression model, the age of stations variable and counties as dummy variables were included in the model, but both became insignificant in all equations, so they were dropped from all equations.

Table 5-8 Multiple regression models for change in housing value (2000-2014)

Independent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Transportation Accessibility Variables										
LnDis2station	.287 (1.044)	.280 (1.013)	.270 (.984)	.376 (1.401)	.396 (1.467)	.390 (1.459)	.433 (1.617)	.462* (1.769)	.478* (1.678)	.482** (1.989)
LnDis2hgy	-.666*** (-4.558)	-.668*** (-4.563)	-.650*** (-4.447)	-.461*** (-3.112)	-.462*** (-3.118)	-.429*** (-2.888)	-.380** (-2.529)	-.336** (-2.285)	-.344** (-2.344)	-.310** (-2.131)
LnDis2Down	.240 (1.467)	.244 (1.485)	.247 (1.512)	.415** (2.545)	.456*** (2.615)	.362** (2.190)	.401** (2.417)	.402** (2.485)	.392** (2.423)	.521*** (3.163)
Socioeconomic Attribute Variables										
LnΔIncome	.176*** (3.425)	.177*** (3.430)	.177*** (3.452)	.176*** (3.521)	.176*** (3.521)	.172*** (3.433)	.168*** (3.377)	.123** (2.474)	.115** (2.302)	.102** (2.056)
LnΔCollege								.204*** (4.928)	.217*** (5.144)	.178*** (4.267)
LnΔEmplyed									-.074 (-1.517)	
LnΔBlk	-.057 (-1.441)	-.059 (-1.472)	-.063 (-1.586)	-.071* (-1.851)	-.072* (-1.871)	-.069* (-1.792)	-.066* (-1.714)	-.064* (-1.700)	-.053 (-1.403)	-.052 (-1.406)
LnΔHisp		.015 (.336)								
Location Attributes Variables										
LnΔPopDen			.081 (1.555)							
LnΔJob				.149*** 5.023	.152*** (5.060)	.145*** (4.883)	.147*** (4.983)	.111*** (3.744)	.116*** (3.897)	.097*** (3.246)
Dum_TOD	1.309*** (5.122)	1.312*** (5.125)	1.247*** (5.045)	1.257*** (5.045)	1.251 (5.016)	1.302*** (5.216)	1.225*** (4.857)	1.057*** (4.260)	1.034*** (4.165)	.773*** (2.954)
Dum_RidPark							-.540* (-1.908)	-.525* (-1.902)	-.564** (-2.039)	-.565** (-1.991)
Proximity to Amenities										
LnDis2School						.351* (1.855)	.417** (2.175)	.284 (1.506)	.290 (1.538)	.377** (1.973)
LnDis2Park					-.130					

Table 5-8—*Continued*

					(-.665)					
LnDis2Mall										-.760*** (-3.150)
R^2	.252	.252	.257	.297	.298	.304	.310	.351	.355	.368
Adj R^2	.241	.239	.243	.285	.284	.289	.294	.334	.336	.349
C$_p$ Stat.	86.73	88.73	85.21	57.04	58.33	54.11	51.88	25.01	24.20	15.04
K+1	7	8	8	8	9	9	10	11	12	12

Dependent Variable: LnΔHousvalue
t statistics in parentheses
* significant at the 0.10; ** significant at the 0.05 level; *** significant at the 0.01 level

In Table 5-8, one independent variable included in the first equation is not significant at any level, but because of its prominence in the prior literature, it should remain in the remainder of the regression models. Anjomani (2016) clarifies that if the purpose of the research is to establish a relationship and not to forecast and if there are a couple of independent variables that the literature suggests should be in the model regardless of their significance, then these variables should be kept in the model. As the control independent variables that are not considered to be major factors are added one by one into the regression model, if the variable is not significant, it will be removed from the equation; then, all regression models are evaluated based on criterions, including the improvement of adjusted R^2 and Cp statistic that should be close to or less than (K+1). As a result, the best model explaining changes in housing values next to rail transit station is number 10 because it has the highest adjusted R^2 and Cp statistic in this equation is the closest one to (K+1).

Table 5-9 shows the summary of the best model where R^2 is .368, which means how much of the variance in the dependent variable is explained uniquely or jointly by the chosen independent variables. In this model, the independent variables explain almost 37% of the variation of $Ln(\Delta Housvalue+1)^2$. Moreover, the highest adjusted R^2 is found in this model, which is .349. The table of (ANOVA) shows that the significance of the model is (0.000)—meaning this model is significant at a 0.01 level. Accordingly, the group of chosen independent variables can truly predict the difference between housing value in proximity to rail stations within the period between 2000 and 2014.

Table 5-9 Model 1 summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.537	.368	.349	2.452

As mentioned earlier, the null hypothesis (H_0: $\beta = 0$) for research question 1 might be written as: change in housing value, for the period between 2000 and 2014, within proximity to rail transit stations in the DFW area does not exhibit any changes. However, the alternate hypothesis (H_a: $\beta \neq 0$) is that proximity to rail stations has a statistically significant impact on the change in the value of housing units. Therefore, to reject or accept the null hypothesis, regression models perform a statistical test to compute

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the p-value (also called the probability) (Wooldridge, 2013). A smaller p-value reflects the smaller probability of error, but the rejection rule is that the null hypothesis is only rejected in favor of alternative hypothesis at the 5% significant level (Wooldridge, 2013).

Table 5-10 shows the results of the chosen multiple regression model that includes the coefficients and the corresponding significant levels (p-value). Almost all estimated coefficients are statistically significant at the 5% level since the t-value is greater than 1.96. Accordingly, the null hypothesis can be rejected at a 95% confidence level and this means also that the independent variables are a representation of the population. However, some of the independent variables that directly relate to the dependent variables and are not statistically significant have not been dropped from the model because the literature suggests that they should be in the model regardless of their significance (Anjomani, 2016). The final regression model results can be written as this regression equation:

$$\text{Ln}(\Delta \text{Housvalue}+1)^2 = 16.179 + .482\ \text{Ln}(\text{Dis2station}) - .310\ \text{Ln}(\text{Dis2hgy}) + .521\ \text{Ln}(\text{Dis2Down}) + .102\ \text{Ln}(\Delta \text{Income}+1)^2 + .178\ \text{Ln}(\Delta \text{College}+1)^2 - .052\ \text{Ln}(\Delta \text{Blk}+1)^2 + .097\ \text{Ln}(\Delta \text{Job}+1)^2 + .773\ (\text{Dum\_TOD}) - .565\ (\text{Dum\_RidPark}) + .377\ (\text{LnDis2School}) - .760\ \text{Ln}(\text{Dis2Mall})$$

(5-3)

As was discussed before, in log-log (double log) models, the coefficients are the elasticity of the change in housing value between 2000 and 2014, with respect to the independent variables that are also measuring changes between 2000 and 2014. Therefore, as mentioned before, to keep the interpretations of the variables less confusing, the word "change" will not be used. From the above regression equation, the following conclusions can be drawn. Transportation accessibility variables show unexpected coefficient signs, but all of them are statistically significant. The findings show that the distance to rail station and downtown coefficients are positive, while the distance to highway ramp coefficient is negative. The coefficient 0.482 means that, holding all independent variables as fixed, one percent increase in the distance between the block group and the closest rail station is predicted to increase $\text{Ln}(\Delta \text{Housvalue}+1)^2$

by 0.482, which translates into an approximate 0.272%[6] increase in median housing value between 2000 and 2014. This means that as distance increases by 10% from the rail station, housing value increases by around 3%.

In addition, when distance from the closest city's downtown to the centroid of a selected block group increases by one percent, median housing value increases by about 0.30% when holding all other variables constant. However, a one-percent increase from the closest highway ramp to the centroid of a selected block group leads to a decline of the median housing value by 0.143% when holding all independent variables constant. This can be translated to for every 10% increase in the distance from highway ramp, housing value declines by approximately 1.5%.

It is observed that variables related to proximity to amenities have unexpected signs. Distance to the closest school has a positive relationship and distance to closest shopping mall has a negative relationship with the median housing value in the study area between 2000 and 2014. Among proximity to amenities variables, distance to the closest shopping mall is the most statistically significant variable. A one percent increase in distance from the closest shopping mall to the centroid of the selected block groups lowers the median housing value by 0.32% in the period between 2000 and 2014. This means that the closer the houses are to shopping malls, the higher change in value. In other words, when the distance from the nearest shopping mall rises by 10%, housing value declines by about 3.2%. However, when the distance increases by 1% from the centroid of selected block groups to the closest school, the median house value increases by 0.21%, while controlling for all other variables.

In this model, it is observed that all selected socioeconomic variables have the expected signs. Residents' income, the number of jobs, and the number of college educated residents have a positive relationship with the dependent variable. The change in the number of black residents has a negative correlation with the independent variable. Literal interpretation follows that for every one-percent increase in individual income within the selected block groups located within one mile from stations, housing value

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6 Since I used *Ln(ΔHousvalue+1)²*, I needed to scale back coefficient to *Ln(ΔHousvalue)* to find the original value of *Y*, so, I followed this process to transform back the coefficient of *Ln(Dis2station)*, whose value was 0.480:

$Ln(Y+1)^2 = 0.482$

$2\ Ln(Y+1) = 0.482;\ 2\ Ln(Y+1)/2 = 0.482/2$

$Ln(Y+1) = 0.241$

$2.718^{0.241} = (Y+1);\ 1.272 = (Y+1);\ Y = 0.272$

between 2000 and 2014 increases by about 0.102% when the effects of all the other variables are held constant. In addition, a one percent increase in the number of jobs within the block groups next to rail stations leads to, on average, a 0.097% increase in housing value between 2000 and 2014, while controlling for all other variables. This means that for each increase of 10% in the number of jobs, housing value increases by about 1%, which means that this this variable is very significant. Furthermore, the variable considering the change in number of college-educated residents is the most statistically significant variable among socioeconomic variables; a one-percent increase in college educated residents increases the median housing value by approximately 0.178 % in the period between 2000 and 2014, with the effects of all the other variables held constant. However, when black residents increase in the selected block groups by one percentage, the median housing value falls by .052%, holding all other independent variables fixed; meaning a 10% increase in black residents lowers median housing value by 0.5%. Unexpectedly, the coefficients of black residents become insignificant. Yet, this variable is one of the major factors affecting housing value, as mentioned in the theories and literature review, so it has been kept in the model.

As was discussed earlier, the logarithmic form is not used with dummy variables. Dummy variable coefficients have a percentage interpretation (Wooldridge, 2013). It can be noticed that all dummy variables about the location of selected block groups have the expected signs. Those dummy variables include whether the rail station has been developed as TOD or non-TOD, and whether the rail transit station is associated with park and ride facilities. Accordingly, median housing value within block groups that have developed as a TOD is 100*[exp(0.47)-1] = 60%[7] higher than the median housing value of block groups considered as non-TOD in the period between 2000 and 2014. This independent variable is the most statistically significant variable among location attribute variables. Finally, the median of housing value within block groups next to rail station that are associated with park and ride facilities is lower by about 22% than the block groups without parking facilities next to them. Below, Table 5-10 shows the results of best model for change in housing value between 2000 and 2014.

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7 After transforming the coefficient back to its original value, I used the process of interpretation of semi-elasticity ($\Delta x = (100*\beta)$ %ΔY). Wooldridge (2013) adds that this process may result in inaccurate results, so he suggested to use this formula instead: $100*[exp(\beta)-1]$ (p. 191-192).

Table 5-10 Results of the best multiple regression model of the change in housing value (2000-2014)

Coefficients[a]					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	16.179	1.077		15.016	.000
LnDis2station	.482	.259	.072	1.989	.045
LnDis2hgy	-.310	.146	-.095	-2.131	.034
LnDis2Down	.521	.165	.143	3.163	.002
LnΔIncome	.102	.049	.088	2.056	.040
LnΔCollege	.178	.042	.195	4.267	.000
LnΔBlk	-.052	.037	-.059	-1.406	.160
LnΔJob	.097	.030	.150	3.246	.001
Dum_TOD	.773	.262	.137	2.954	.003
Dum_RidPark	-.565	.277	-.060	-1.991	.042
LnDis2School	.377	.188	.055	1.973	.045
LnDis2Mall	-.760	.241	-.159	-3.150	.002

a. Dependent Variable: LnΔHousvalue

5.5.2   Regression Analysis and Results for Research Question 2: Change in White Residents (2000-
2014) Due to Proximity to Rail Stations

The second regression model estimates the changes in the number of white residents between 2000 and 2014 as a function of proximity to rail stations in the DFW area and other controlling factors such as social, economic, and spatial factors (e.g. the housing market). The final model is formulated to examine the impact of proximity to rail transit stations on housing value is as follows:

$$\Delta \text{ white residents (2000-2014)} = \alpha + \beta_1 (\text{Dis2station}) + \beta_2 (\text{Dis2hgy}) + \beta_3 (\text{Dis2Down}) + \beta_4 (\Delta\text{Income}) + \beta_5 (\Delta\text{College}) + \beta_6 (\Delta\text{Emplyed}) + \beta_7 (\Delta\text{Blk}) + \beta_8 (\Delta\text{Hisp}) + \beta_9 (\Delta\text{Housvalue}) + \beta_{10} (\Delta\text{Rent}) + \beta_{11} (\Delta\text{PopDen}) + \beta_{12} (\Delta\text{Job}) + \beta_{13} (\text{Dum\_TOD})$$

(5-4)

As was discussed in model building process, only independent variables that directly relate to the research question will be included in the first regression model. These independent variables include the main factor which is the distance to rail station. Also, it includes: the distance to the closest downtown, the income of residents, whether residents are college educated, whether residents have jobs, and population density. Then, as was discussed earlier, the independent variables will be added one by one based on their importance and common usage in literature into the regression model until all the variables are exhausted. Table 5-11 shows the regression equations that have been run to find the best model. In the initial formulation of the regression model, the age of stations variable and counties as dummy variables were included in the model, but both became insignificant in all equations, so they were dropped from all equations.

Table 5-11 Multiple regression models for change in the number of white residents (2000-2014)

Independent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Transportation Accessibility Variables							
LnDis2station	-.406** (-2.041)	-.399** (-2.012)	-.473** (-2.428)	-.496** (-2.536)	-.486** (-2.500)	-.515*** (-2.638)	-.481** (-2.489)
LnDis2hgy						.155 (1.460)	.232** (2.162)
LnDis2Down	.311*** (2.659)	.330*** (2.821)	.365*** (3.176)	.384*** (3.313)	.393*** (3.403)	.372*** (3.204)	.464*** (3.941)
Socioeconomic Attribute Variables							
LnΔIncome	-.065* (-1.722)	-.057 (-1.484)	-.055 (-1.477)	-.052 (-1.387)	-.041 (-1.086)	-.042 (-1.097)	-.033 (-.872)
LnΔCollege	.078** (2.518)	.097*** (2.981)	.114*** (3.563)	.116*** (3.631)	.127*** (3.897)	.130*** (3.982)	.112*** (3.417)
LnΔEmplyed	.240*** (6.158)	.236*** (6.056)	.227*** (5.946)	.224*** (5.853)	.227*** (5.958)	.231*** (6.062)	.212*** (5.569)
LnΔBlk	.027 (.915)	.024 (.808)	.012 (.406)	.012 (.420)	.008 (.272)	.010 (.349)	.003 (.094)
LnΔHisp			.161*** (4.555)	.157*** (4.417)	.162*** (4.591)	.159*** (4.482)	.158*** (4.515)
Housing Market Variables							
LnΔHousvalue		-.063* (-1.838)	-.061* (-1.806)	-.051 (-1.496)	-.058* (-1.738)	-.058* (-1.751)	-.070** (-2.038)
LnΔRent					-.074** (-1.970)	-.073** (-1.968)	-.079** (-2.121)
Location Attributes Variables							
LnΔPopDen	.195*** (4.885)	.202*** (5.035)	.132*** (3.143)	.141*** (3.309)	.129*** (3.080)	.132*** (3.154)	.147*** (3.523)
LnΔJob							.077*** (3.427)
Dum_TOD				-.232 (-1.232)			
R²	.340	.346	.380	.382	.386	.389	.408
Adj R²	.328	.332	.365	.366	.370	.372	.389
Cp Stat.	54.20	51.73	28.37	28.88	25.90	25.66	13.49
K+1	8	9	10	11	11	12	13

Dependent Variable: LnΔWhite
t statistics in parentheses
* significant at the 0.10; ** significant at the 0.05 level; *** significant at the 0.01 level

A couple of the independent variables have been kept in all regression equations even if they are not significant. The rest of the control variables are added one by one in the model until the best regression model is found. Model number seven is the best model from the seven regression equations that have been tested as shown in Table 5-11. This model explains the changes in the number of white residents in the block groups within the one-mile buffer around rail stations, as it has the highest adjusted R^2 and Cp statistic.

Table 5-12 shows the summary of the best model where R^2 is .408. This means that around 41% of the variance in the dependent variable $(Ln(\Delta White+1)^2)$ is explained uniquely or jointly by the chosen independent variables. Also, this table includes the highest adjusted R^2 in all regression equations that have been tested, which is 0.389. The table of (ANOVA) shows the significance of the model is (0.000), which means this model is significant at a 0.01 level or the model is significant at a 99% level. Accordingly, the group of chosen independent variables can actually predict the number of white residents in proximity to rail stations within the period between 2000 and 2014.

Table 5-12 Model 2 summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.555	.408	.389	1.825

The null hypothesis (H_0: $\beta = 0$) for research question 2 can be written as: between 2000 and 2014, the race of residents does not exhibit any change; specifically, the total number of white residents living in neighborhoods within one mile radius around rail transit stations does not exhibit any significant change. However, the alternate hypothesis (H_a: $\beta \neq 0$) is that adjacency to rail stations has a statistically significant impact on changes in the number of white residents for the period between 2000 and 2014. Therefore, to reject or accept the null hypothesis, p-value should be computed. Table 5-13 shows the results of the chosen multiple regression model that includes the coefficients and the corresponding significant levels (p-value). Almost all estimated coefficients are statistically significant at the 5% level (95% confidence interval) since the t-value is greater than 1.96. Accordingly, the null hypothesis can be rejected at a 95% confidence level and those variables are representative of the population. Some of the independent variables, such as income of residents and the number of black residents, are directly related to the dependent variables and are statistically insignificant. Yet, these variables are kept in the model because the literature suggests that these variables should be in the model regardless of their significance (Anjomani, 2016). The final regression model results can be written as this regression equation:

$$Ln(\Delta White+1)^2 = 7.299 - .481\ Ln(Dis2station) + .232\ Ln(Dis2hgy) + .464$$

$$Ln(Dis2Down) -.033\ Ln(\Delta Income+1)^2 + .112\ Ln(\Delta College+1)^2 + .212$$

$$Ln(\Delta Emplyed+1)^2 + .003\ Ln(\Delta Blk+1)^2 + .158\ Ln(\Delta Hisp+1)^2 - .070 \qquad (5\text{-}5)$$

$$Ln(\Delta Housvalue+1)^2 - .079\ Ln(\Delta Rent+1)^2 + .147\ Ln(\Delta PopDen+1)^2 + .077$$

$$Ln(\Delta Job+1)^2$$

From this regression equation, the following conclusions can be drawn. First of all, this model only contains a log-log (double log) model since all dummy variables have been dropped due their insignificance. Moreover, as a good number of the remaining variables are also measuring changes between 2000 and 2014, the word "change" will not be used in the researcher's interpretations of the variables (as previously mentioned). Transportation accessibility variables show the expected coefficient signs. This means that an inverse relationship exists between the distance to rail transit stations and the number of white residents, while it is as expected that the distance to highway ramps and to the city downtown have a positive relationship with the number of white residents within the selected block groups. As expected, the coefficient of the distance to rail stations is -0.481, which translates into -0.21% because $Ln(\Delta White+1)^2 = -0.481\%$. This means, when holding all independent variables constant, a one-percent increase in the distance between a rail station and the centroid of closest block groups leads to a reduction 0.21% in the white population. Likewise, when the distance from a rail station increases by 10% feet, the number of white residents also decline by 2.1%, when controlling for all other variables. However, when the distance from the closest highway ramp to the centroid of the selected block groups increases by one percent, the number of white residents increases by about 0.12%, holding all other independent variables as fixed. This indicates that a 10% increase in distance from highway ramps results in an increase of white residents by 1.2%. The distance to downtown variable is the most statistically significant independent variable among the transportation accessibility variables. Distance to a downtown also shows a positive sign, which means that a one percent increase in the distance from the closest city's downtown to the selected block groups next to rail station results in 0.26% more in white

residents, when controlling for all other variables. This shows that as the distance increases by 10% from the downtown, the number of white residents increase by about 2.6%.

It can be observed that income and the number of Hispanic residents have the most unexpected signs; residents' income has a negative relationship with the dependent variable, while college educated residents, employed residents, and Hispanic and Latino residents within the selected block groups have a positive relationship with the dependent variable. Unexpectedly, a 1% increase in individual income within the selected block groups reduces the number of white residents by 0.033% in the period between 2000 and 2014, when the effects of all the other variables are held constant. This outcome is contrary to most the most of the literature as shown in Chapter 2. However, a one percent increase in residents with at least a bachelor's degree within the block groups next to rail stations leads to, on average, a 0.112% increase in the number of white residents between 2000 and 2014. This means that if the number of residents with at least a bachelor's degree increases by 10%, a rise in the number of white residents within the selected block groups next to rail transit stations will increase by 1.1% persons.

As expected, if the number of employed residents, within the study area, increases by one percent, the number of white residents will increase by 0.212%, when controlling for all other variables. In other words, when the number of employed residents increases by 10%, the number of whites rises by 2.1%. Additionally, one percentage more in the number of Hispanic and Latino residents within the block groups next to rail stations leads to, on average, a 0.158 % increase in the number of white residents between 2000 and 2014, holding all independent variables as fixed. Employed residents and Hispanic residents are the most significant independent variables among the variables related to socioeconomic attributes of residents, but they have a very small impact on the number of whites.

Some of the factors related to the housing market can play a significant role in the changing the race of residents. This means housing value and rent can affect the number of white and black residents within the selected neighborhood. In this study, median housing value and median contract rent are included in the model to examine their impact on the number of white residents within the selected block groups. Based on the results, they are statistically significant and have an unexpected sign. Unexpectedly, a one percent increase in the median housing value reduces the number of white residents

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by 0.070%, holding all other variables constant. In other words, when the median housing value increases by 10%, the number of white residents declines by around 0.7% within the selected block group. In addition, a one-percent increase in housing rent decreases the number of white residents by about 0.079%, when other independent variables are fixed. While both housing value and rent variables are statistically significant, they have a small impact on the number of white residents within the study area.

From the location attribute variables examined, population density alone and the number of jobs become statistically significant. The analysis shows that a 1% increase in population density within the study area between 2000 and 2014 results in an increase of the number of white residents by 0.147%, keeping all other factors constant. This means an increase of 10% in population density per acre within a selected block group leads to an increase in the number of white residents by 1.5% per block group. Also, as the number of jobs within the selected block groups also increases by one percent, this leads to an increase of 0.077% in the number of white residents, holding all other variables constant.

Table 5-13 Results of the best multiple regression model of the change in housing value (2000-2014)

Coefficients[a]					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	7.299	.977		7.474	.000
LnDis2station	-.481	.193	-.101	-2.489	.013
LnDis2hgy	.232	.107	.093	2.162	.031
LnDis2Down	.464	.118	.167	3.941	.000
LnΔIncome	-.033	.038	-.037	-.872	.384
LnΔCollege	.112	.033	.159	3.417	.001
LnΔEmplyed	.212	.038	.251	5.569	.000
LnΔBlk	.003	.028	.004	.094	.925
LnΔHisp	.158	.035	.198	4.515	.000
LnΔHousvalue	-.070	.034	-.091	-2.038	.042
LnΔRent	-.079	.037	-.090	-2.121	.035
LnΔJob	.077	.023	.156	3.427	.001
LnΔPopDen	.147	.042	.163	3.523	.000

a. Dependent Variable: LnΔWhite

5.5.3 Regression Analysis and Results for Research Question 3: Change in Population Density (2000-2014) Due to Proximity to Rail Stations

The third regression model estimates the changes in population density in the study area between 2000 and 2014, as a function of the proximity to rail stations in the DFW area and other controlling factors, such as: social, economic, and spatial factors like the housing market. The final model is formulated to examine the impact of proximity to rail transit station on housing value as follows:

$$Ln(\Delta PopDen+1)^2 = \alpha + \beta_1 (Dis2station) + \beta_2 (Dis2hgy) + \beta_3 (Dis2Down) + \beta_4$$
$$Ln(Dis2MajEmplo) + \beta_5 Ln(\Delta Income+1)^2 + \beta_6 Ln(\Delta Emplyed+1)^2 + \beta_7$$
$$Ln(\Delta White+1)^2 + \beta_8 Ln(\Delta Hisp+1)^2 + \beta_9 Ln(\Delta Poverty+1)^2 + \beta_{10} Ln(\Delta HousValue+1)^2$$
$$+ \beta_{11} Ln(\Delta Job+1)^2 + \beta_{12} (Dum\_TOD) + \beta_{13} (Dum\_RidPark)$$

(5-6)

As was discussed in model building process, the regression model will be run with the independent variables directly related to the research question. These variables represent the major factors expected to have the largest contribution on explaining the population density within the selected block groups to rail stations. The variables include: distance to rail stations, distance to a highway ramps, distance to the closest downtown, median housing value, and whether the station has been developed as TOD. Independent variables were added one by one based on their importance and common usage in literature into the regression model until all the variables were exhausted. Table 5-14 shows the regression equations ran to find the best model. As was mentioned before, in the initial formulation of the regression model, the age of stations variable and counties as dummy variables were included in the model, but both became insignificant in all equations, so they were dropped from all equations.

Table 5-14 Multiple regression models for change in population density (2000-2014)

Independent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Transportation Accessibility Variables									
LnDis2station	.158 (.636)	.326 (1.391)	.324 (1.379)	.318 (1.388)	.319 (1.390)	.323 (1.399)	.425* (1.884)	.461 (1.968)	.472** (1.975)
LnDis2hgy	-.168 (-1.248)	-.047 (-.372)	-.049 (-.381)	-.027 (-.217)	-.027 (-.217)	-.020 (-.152)	-.066 (-.540)	-.165 (-1.901)	-.221** (-1.998)
LnDis2Down	-.050 (-.341)	.009 (.066)	.007 (.048)	-.010 (-.076)	-.013 (-.095)	-.005 (-.035)	-.090 (-.677)	-.027 (-.211)	-.102 (-.781)
LnDis2MajEmplo						-.030 (-.203)			
Socioeconomic Attribute Variables									
LnΔIncome					-.008 (-.181)				
LnΔEmplyed		.325*** (7.855)	.326*** (7.837)	.296*** (7.174)	.295*** (7.131)	.294*** (7.026)	.219*** (5.041)	.205*** (4.934)	.216*** (5.196)
LnΔWhite							.244*** (4.635)	.169*** (3.288)	.189*** (3.655)
LnΔHisp								.255*** (6.728)	.248*** (6.554)
LnΔPoverty				.192*** (4.367)	.192*** (4.363)	.191*** (4.351)	.146*** (3.303)	.090** (2.090)	.089** (2.093)
Housing market Variables									
LnΔHousvalue	.055 (1.312)	.054 (1.365)	.054 (1.368)	.065* (1.675)	.066* (1.680)	.063 (1.588)	.063* (1.666)	.060* (1.654)	.080** (2.166)
Location Attributes Variables									
LnΔJob									-.060*** (-2.407)
Dum_TOD	.656*** (2.771)	.701*** (3.155)	.705*** (3.129)	.664*** (3.044)	.667*** (3.045)	.662*** (3.027)	.698*** (3.270)	.757*** (3.716)	.750*** (3.704)
Dum_RidPark			.028 (.113)						
R²	.136	.253	.253	.287	.287	.288	.325	.397	.406
Adj R²	.125	.241	.239	.275	.273	.273	.311	.382	.390
C$_p$ Stat.	204.90	119.30	121.30	95.84	97.84	97.09	69.39	17.48	12.74
K+1	6	7	8	8	9	9	9	10	11

Dependent Variable: LnΔPopDen
t statistics in parentheses
* significant at the 0.10; ** significant at the 0.05 level; *** significant at the 0.01 level

It can be observed from Table 5-14 that some of the independent variables that related directly to the research question and that were included in the first equation are insignificant at all levels. However, the researcher has kept these variables in the rest of the regression models because the literature suggests that they should be in the model, regardless of their significance. Insignificant variables have been removed from the regression models. The best model was evaluated based on criterion mentioned earlier. As a result, the best model that explains the changes in population density next to rail transit

stations after the analysis is model number 10, as it has the highest adjusted R^2 and the Cp statistic in this equation is the closest to (K+1).

Table 5-15 shows the summary of the best model where R^2 is 0.406. This means that the independent variables can explain nearly 40% of the variation in $Ln(\Delta PopDen+1)^2$ between 2000 and 2014. The highest adjusted R^2 is found in this model, which is 0.390. The table of (ANOVA) shows that the significance of the model is (0.000) meaning this model is significant at a 0.01 level. Accordingly, the group of chosen independent variables can predict the difference between housing value in proximity to rail stations within the period between 2000 and 2014.

Table 5-15 Model 3 summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.553	.406	.390	2.023

The null hypothesis (H0: β = 0) for research question 3 can be written as: the population density for the period between 2000 and 2014 in the area within the one-mile buffer around rail stations does not exhibit any significant changes due to their proximity to rail stations. However, the alternate hypothesis (Ha: β ≠ 0) is that proximity to rail stations has a statistically significant impact on population density for the period between 2000 and 2014. Therefore, to reject or accept the null hypothesis, regression models perform a statistical test to compute the p-value (Wooldridge, 2013).

Table 5-16 shows the results of the chosen multiple regression model that includes the coefficients and the corresponding significant levels (p-value). Most of the coefficients are statistically significant at the 5% level since they have a t-value is greater than 1.96. Accordingly, the null hypothesis can be rejected at a 95% confidence level and these variables are representative of the population. However, some of the independent variables directly relate to the dependent variables and are not statistically significant have not been dropped from the model because the literature suggests that they should be in the model, regardless of their significance (Anjomani, 2016). The final regression model results can be written as this regression equation:

$$\text{Ln}(\Delta\text{PopDen}+1)^2 = -7.102 + .472\ \text{Ln}(\text{Dis2station}) - .221\ \text{Ln}(\text{Dis2Hgy}) - .102$$
$$\text{Ln}(\text{Dis2Down}) + .216\ \text{Ln}(\Delta\text{Emplyed}+1)^2 + .189\ \text{Ln}(\Delta\text{White}+1)^2 + .248$$
$$\text{Ln}(\Delta\text{Hisp}+1)^2 + .089\ \text{Ln}(\Delta\text{Poverty}+1)^2 + .080\ \text{Ln}(\Delta\text{Housvalue}+1)^2 + .750$$
$$(\text{Dum\_TOD}) - .060\ \text{Ln}(\Delta\text{Job}+1)^2$$

(5-7)

From the above regression equation, the following conclusions can be drawn. All variables within the equation, except for distance and dummy variables, measure changes between 2000 and 2014 so, as mentioned before, to avoid redundancy, the word "change" will not be used. Transportation accessibility variables show different coefficient signs. Unexpectedly, the relationship between the distance to a rail station and population density is positive. This means that a one percent increase in the distance from a rail transit station to the centroid of a block group is predicted to increase $\text{Ln}(\Delta\text{PopDen}+1)^2$ by 0.472. This translates into an approximate 0.27% increase in population density between 2000 and 2014, holding all independent variables as fixed. This means that the closer to a rail station, the lower the population density of block groups.

As expected, the distance to a highway ramp coefficient and the distance to the closest downtown coefficient are negative. An increase of one percent from the closest highway ramp to the selected block group leads to a decline of population density by 0.105%, holding all independent variables constant. In other words, for each 10% a group block is farther from highway ramp, there is a decrease of 1% in the population density per acre within the block group. In addition, a one percent increase in the distance between the closest downtown and the selected block groups decreases the population density by 0.05%, holding all other independent variables as fixed. This means that the shorter the distance to a highway ramp or city's downtown, the higher the density. All results of the variables related to transportation accessibility show a small impact on population density. Also, the coefficients for distance to the closest city's downtown become insignificant with this regression model even though it is considered as one of the major factors expected to affect population density.

In this model, all variables related to socioeconomic attributes of the residents have positive signs, which means a positive relationship with the dependent variable. Based on the literature, it was

expected that the number of employed residents and white residents within the study area would show a negative relationship with population density. However, the regression model is contrary to the expectation. In fact, the number of employed residents, white residents, and Hispanic residents are the most significant independent variables among the socioeconomic variables. A one percentage increase in employed residents within the study area increases the population density between 2000 and 2014 by 0.216%, holding all the other variables constant. This means that an increase of employed residents of 10% within a block group leads to an increase in the population density by 2.16% people per acre within the study area. In addition, a one percent increase in the number of white residents within the selected block groups next to rail stations leads to, on average, a 0.189% increase in population density per acre between 2000 and 2014.

Furthermore, a one percentage increase in Hispanic residents has an increase in population density of approximately 0.248% in the period between 2000 and 2014, when the effects of all the other variables are held constant. This means that an increase of 10% in Hispanic residents within the selected block group leads to an increase of 2.5% in population density per acre within the selected bock group.

Change in the level of poverty has a small impact on population density within the selected block groups. With a one percent increases in poverty levels, population density increases by 0.089%, while controlling for all other variables. Only the median housing value variable becomes significant among the variables related to housing market variables. In this model, a one percent increase in the median housing value within a block group results in a .080% increase in population density per acre, holding all other variables constant. This shows a very small impact on population density.

Independent variables related to location attributes show the expected signs. The number of jobs variable shows a negative sign and the variable is significant. This means that as the number of jobs within the selected block group increases by one percent, population density declines by 0.060%. This means that if the number of jobs increases by 10%, population density per acre is reduced by 0.6% within the selected block groups, holding all variables constant. Only one dummy variable within this model becomes significant—whether the rail station has been developed as TOD or non-TOD— and the coefficient sign is positive as expected. For dummy variables, the coefficients have a percentage

interpretation so, population density per acre in block groups that developed as a TOD is

100*[exp(0.454)-1] = 58% higher than the population density of block groups that are considered non-

TOD in the period between 2000 and 2014.

Table 5-16 Results of the best multiple regression model of the change in population density (2000-2014)

Coefficients[a]					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-7.102	.884		-8.030	.000
LnDis2station	.472	.216	.075	1.975	.047
LnDis2Hgy	-.221	.119	-.082	-1.998	.040
LnDis2Down	-.102	.130	-.033	-.781	.435
LnΔEmplyed	.216	.042	.231	5.196	.000
LnΔWhite	.189	.052	.171	3.655	.000
LnΔHisp	.248	.038	.281	6.554	.000
LnΔPoverty	.089	.043	.088	2.093	.037
LnΔHousvalue	.080	.037	.094	2.166	.031
Dum_TOD	.750	.203	.156	3.704	.000
LnΔJob	-.060	.025	-.109	-2.407	.016

a. Dependent Variable: LnΔPopDen

Chapter 6

Findings, Conclusions, and Implications

This study investigates the changes in housing value, race, and population density between 2000 and 2014 in block groups within a one-mile buffer around rail stations located in the Dallas-Fort Worth (DFW) metropolitan area, specifically in the four counties served by passenger rail transit systems including Collin, Dallas, Denton, and Tarrant counties. In addition, this research study compares the economic, social, and spatial changes of the block groups within a one-mile radius around rail stations (study area) to the rest of block groups within the four counties (non-station areas). Data from different sources were collected to investigate the relationships and changes of economic, social, and spatial factors within the block groups located in the study area and non-station areas. Data analysis was then conducted that started with the presentation of a descriptive analysis of changes in the study area, as well as outside of the study area within the four counties. This was followed by running regression models to investigate the relationships between the selected variables. The sections below will discuss the research findings based on the comparison of the study area between 2000 and 2014, a comparison of the study area to non-station areas between 2000 and 2014, and the results of the regression models that were designed to answer the three research questions. Then, a summary of the research will be presented to suggest some solutions for increasing housing value, population density, and attracting a more diverse population to the study area, followed by recommendations and possible implications for rail transit development, accessibility, and TOD development policies and programs.

6.1 Findings and Discussion

This section will begin with the findings of the descriptive analysis for the study area and the non-station areas. The first part discusses the statistical descriptive analysis of changes in some economic, social, and spatial factors within the study area, and compares the changes to the non-station areas. The changes can be noticed visually in the maps presented in Chapter 4, and the results of Kruskal-Wallis test show that differences between the percent changes in the study area and non-station areas are statistically significant. First of all, the descriptive analysis suggests that the median percent change of population and population density within block groups located in the study area was 1.50% compared to

about 10% within non-station areas. This indicates that the study area did not experience a greater increase in its number of residents. In fact, many residents left the cities and moved to the outlying areas during the years between 2000 and 2014.

The number of white residents increased within both block groups within the study area and block groups outside the study area. The increase is greater within the study area. The median percent change of the number of white residents within the study area is 22% compared to about 10% the non-station areas. On the other hand, the study area experienced a major decline in the percent change of the number of black residents, which was around -11%, while the median percent change in the number of black residents within the non-station areas increased by 10%. This has led to the conclusion that, over the period of study, some white residents still moved to the study area and many black residents left it.

Regarding the block groups located outside of the study area within the four counties served by transit systems, a major increase of white residents can be seen in many block groups in the south of Dallas, and in the north, the west, and south outlying areas. Also, the number of black residents increased significantly in the several outlying areas surrounding the two major cities, Dallas and Fort Worth, while their numbers declined inside those two major cities. While the increase in the number of Hispanic and Latino residents within the study area is significant (around 30%) between 2000 and 2014, it is a much smaller increase than the increase in these residents within the non-station areas (94%). This increased number of Hispanic and Latino residents can be seen in most of the block groups within the four counties, except some block groups located in downtown Dallas and toward the north, and some block groups within Fort Worth and expanding toward the northeast.

The changes in the number of college graduates, employed residents, and the number of jobs were greater outside the study area than within the study area. The median percent change in residents who have at least a bachelor's degree within the study area was around 14%, while it was 17% in non-station areas between the years 2000 to 2014. Also, the median percent change of employed residents was about 4% within block groups located within one-mile around rail stations, compared to 8.30% in the block groups outside the study area in the period between 2000 and 2014. Furthermore, the median of percent change in the number of jobs per block groups within the study area was 10.61%, compared to

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20.42% in non-station areas between 2000 and 2014. This can be attributed to the increase in the number of subcenters outside the main cities toward the several outlying areas that attract jobs and worker residents.

It can be observed that the change in median housing value did not show a major increase, especially after adjusting for inflation. However, the positive changes are greater in block groups next to rail stations. In the study area, the percent change in the median housing value within the study area was 14% on average between 2000 and 2014, while it was 5% within the non-station areas. Even though the percent change of housing value is greater in the study area, the actual housing value outside the study area is higher than the prices of houses in proximity to rail stations. Median housing rent shows a decline in the medians between 2000 and 2014 in all four counties. The decline is worse within the block groups outside of the study area. The median percent change in housing rent within the study area was -0.72%, compared to -3.58% for the non-station areas during the years 2000 and 2014. While the decline is greater in housing rent outside the study area, the actual housing rent is still higher on average than in block groups within the one-mile buffer around rail stations. Moreover, the median percent change in residents' income for the block groups within the study area is around -12%, compared to -8.77% within block groups outside the one-mile buffer between 2000 and 2014. Notice that the block groups outside the study area experienced a larger decline in income between 2000 and 2014, although actual earnings are still greater between 2000 and 2014 than the income of residents who live next to rail stations. The changes in incomes were more disproportionately severe than the other changes within the study area – and in fact, the increase in housing value is seemingly not an adverse effect, but only so in comparison to the non-study area that experienced less growth, but still has a higher value. These results suggest that although changes in housing value and rent were adverse within the study area, the change in income within the study area was especially disproportionate to other changes. This may indicate that the whole four counties did not experience a class upgrade, as there was a decline in housing value, housing rent, and income.

One of the primary causes of the decrease in housing prices was a collapse of the housing market and reduced incomes resulting from the great recession that happened between 2007 and 2012 in

the United States. Figure 6-1 shows that house prices in Dallas declined in 2006, and reached the lowest price in 2012. However, by the beginning of 2013, housing markets began to recover.
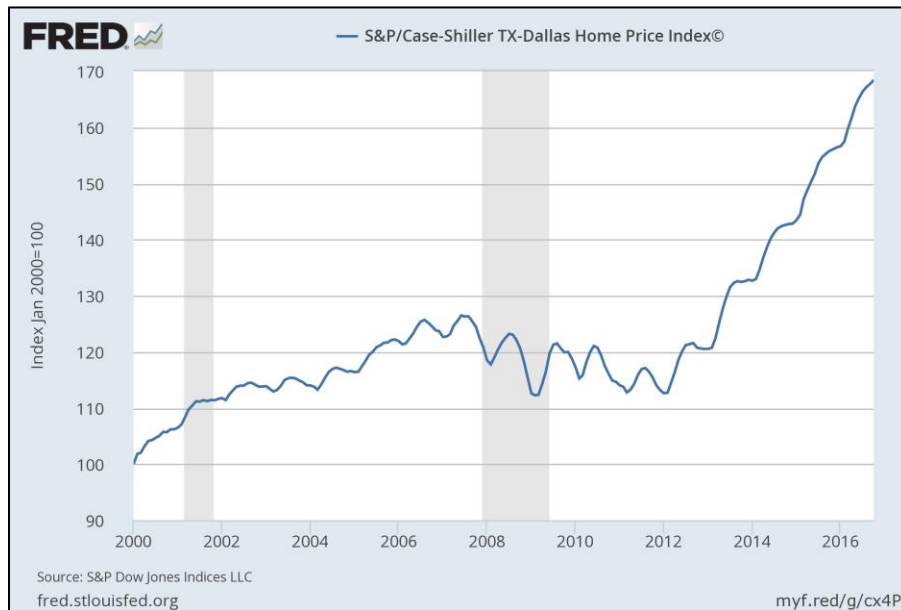
Figure 6-1 Changes in house price between 2000 and 2016

This study seeks to determine which factors affect the change in housing value, population density, and demographic diversity. The findings of the descriptive analysis suggest that the median increase in housing value in the block groups within the one-mile buffer around stations is greater than the median of the non-station areas. Also, there is an increase in the number of white residents within the study area when compared to non-station areas. However, population density experienced a greater increase in non-station areas. Using different methods may yield different findings, so the next section discusses the findings of regression models of the following research questions:

1. Does proximity to rail stations in the DFW area affect median housing value for the period between 2000 and 2014? What are the other controlling factors contributing to affecting housing value next to rail transit stations?

2. What has been the impact of existing rail stations on the racial make-up of residents in neighborhoods surrounding rail transit stations for the period between 2000 and 2014? Do rail

stations attract more white residents to live next to rail transit stations? What are the other

controlling factors affecting these attributes in proximity to rail stations?

3. Do the neighborhoods immediately proximate to rail transit stations experience change in

population density for the period between 2000 and 2014? Also, what are the most important

controlling factors affecting population density in neighborhoods surrounding rail stations?

6.1.1   Findings and Discussion of Research Question 1

Research Question 1: Does proximity to rail stations in the DFW area affect median housing

value for the period between 2000 and 2014? What are the other controlling factors contributing to

affecting housing value next to rail transit stations?

The descriptive analysis indicates that the median housing value within the block groups located

in the buffer of the one-mile around rail stations was around $70,200 in 2000, which increased in 2014 to

about $83,850 (Adjusted for housing price inflation of Dallas city for 2000 base year dollar). The median

of percent change between 2000 and 2014 was around 14%; the number of block groups that

experienced a positive percent change was 320 block groups, while 134 block groups experienced a

negative percent change. For regression model 1, the findings below show the independent variables that

are statistically significant and have an impact on change in median housing value within the study area:

- Transportation accessibility variables:
    - Distance from the selected block groups located within the one-mile buffer around stations to

        the nearest rail station in the study area (LnDis2station) shows a positive correlation with the

        change in median housing value. As the distance from rail transit station increases, the

        change in median housing value is greater, whereas the closer to the station, the lower the

        change in housing value. The findings of the comparisons between the station area and non-

        station areas can support this finding. As discussed before, many residents moved to several

        outlying areas of the four counties served by rail transit systems which resulted in lower

        demand for housing units in proximity to rail stations, and therefore lower housing value. In

        addition, this is supported by some of the available literature that homes in proximity to

        stations might be affected be some negative externalities associated with transit systems,

such as higher crime rates, unpleasant noise, vibration, traffic congestion, and pollution. These factors negatively affect housing values (Bowes & Ihlanfeldt, 2001; Hess & Almeida, 2007). Additionally, most of the existing transit systems within the study area were used as freight railroad corridors, where industrial, warehouses use usually increases along the rail transit right of way which in turn affect housing value negatively. In 2010, the commercial and retail use represents 32%, industrial 7.6%, residential uses 47% and vacant land represents 13.5% within the study area (NCTCOG, 2013b).

- Distance from block groups located within the one-mile buffer around stations to the nearest highway access ramp (LnDis2Hgy) has a negative relationship with median housing value change. This means that houses with access to highway ramps appreciated in value change at a higher rate than homes located farther away from highway ramps. This finding suggests that improved accessibility can play a major role in increasing property value since people are willing to purchase land based on accessibility benefits. In other words, the future savings in commuting time and costs will be transferred to the present increase in property value (Gamble & Davinroy, 1978). Also, the majority of residents in the DFW area are still car-dependent and benefit from lower commuting costs and easier accessibility, so they value the proximity to highway ramps.

- Distance form block groups within the one-mile buffer around stations to nearest city downtown (LnDis2Down) is associated positively with median housing value change. This means there is a greater positive change in housing value for black groups farther away from the city center. As discussed in the literature and supported by the findings of the comparisons of study area to non-stations area, central city traffic congestion, a large number of minorities, aging infrastructure, and old homes play a major role in the continuation of movement of residents toward the outlying areas. Many retailers and businesses subsequently follow their customers to outlying areas areas (Frew & Wilson, 2002). This in turn negatively affects the demand for housing units in proximity to downtowns. This results in a decline in housing value (Armstrong, 1997; Frew & Wilson, 2002).

- Socioeconomic characteristics of residents variables:

  ▪ Change in income of residents 16 years and older (LnΔIncom) and the number of residents with at least a bachelor's degree (LnΔCollege) have a positive relationship with the change in median housing value. This finding shows that as the number of college educated residents and residents' income increase, change in housing value also increases. Income is one of the major determinants of demand; the increase in income results in higher demand (O'Sullivan, 2012). Also, income is correlated with levels of education, but in a nonlinear relationship. This means that as the level of education increases, income rises in different ways (Woolridge, 2013). This attracts higher income residents and an increase in demand for housing units in proximity to stations.

  ▪ Change in the number of black residents (LnΔBlk) has an inverse relationship with the change in median housing value. This means that when the number of black residents rises, the change in housing value declines. This is consistent with the argument that black residents are usually linked to housing value devaluation. In addition, white residents do not desire to live in black neighborhoods. This results in a decline in housing demand among white residents, and lowers housing value (Armstrong, 1997; Massey & Denton, 1993)

- Location attributes variables:

  ▪ Change in the number of jobs within each block group (LnΔJob) is statistically significant and has a positive correlation with the change in housing value. In other words, block groups that have more commercial, retail, and office uses positively affect the change in housing value. This could be an indication of mobility advantages where housing, shopping, and working can be accomplished within short trips or even can be done by walking or bicycling to the destination area (Cervero, 1995). Additionally, this can be an indicative that a job-housing balance is present in the study area where employed residents can reach their workplace, recreation places, schools, and shopping areas with short trips.

  ▪ Neighborhoods next to rail transit stations that were developed as transit-oriented development (Dum_TOD) have a significant positive impact on the change in median housing

value. This means that housing value within block groups developed as a TOD appreciate in value at a greater rate than the block groups that are not developed as TODs. As mentioned in previous studies, TODs are highly desirable amenities where most of residents' needs and services can be reached within walking distance, so property value is affected positively (Gardner, 2007; Mathur & Ferrell, 2012).

▪ Availability of park-and-ride facilities next to rail stations (Dum_RidPark) is associated negatively with the change in median housing value. In the study area, the existence of parking lots next to rail stations affects the change in housing value negatively. Many of the existing studies show that the availability of parking lots next to rail stations decline residential value because of the higher crime rates in the parking lots and in neighborhoods surrounding rail stations (Bowes & Ihlanfeldt, 2001). Another expectation is that parking lots are associated with other negative externalities such as higher traffic congestion and noise. In turn, this decreases housing value in the neighborhoods within proximity to rail stations (Atkinson-Palombo, 2010).

- Proximity to amenities variables:

▪ Distance to closest school (LnDis2School) from block groups located within the one-mile buffer around stations is positively associated with the change in housing value. This implies that the greater the distance from school, the higher the change in housing value. This finding implies that school areas are busy area; schools can cause external diseconomies (e.g. speed restrictions, traffic congestion, and noise from playgrounds) to spill over into the adjacent area (Colwell & Guntennann, 1984; Hendon, 1973). Families with young children may prefer to live in proximity to schools which increase the demand for housing units. On the other hand, retirees, adult families, and seniors do not need to live in proximity to schools.

▪ Distance from block groups located within the one-mile buffer around stations to closest shopping mall (LnDist2mall) has a negative relationship with the change in median housing value. This means the median housing value change is higher in proximity to shopping malls. A possible explanation is that shopping malls can be a source of positive externality when

providing convenience to neighboring residents, such as saving in commute times and costs and increasing accessibility.

6.1.2   Findings and Discussion of Research Question 2

Research Question 2: What has been the impact of existing rail stations on the racial make-up of residents in neighborhoods surrounding rail transit stations for the period between 2000 and 2014? Do rail stations attract more white residents to live next to rail transit stations? What are the other controlling factors affecting these attributes in proximity to rail stations?

The descriptive analysis shows that the median number of white residents within the block groups located within the one-mile buffer around rail stations was 634 persons in 2000, and increased to 806 persons in 2014. The median percent change between 2000 and 2014, was 22%. The number of block groups that experienced a positive percent change in white residents were 302 block groups, while 151 block groups experienced a negative percent change. For the regression model 2, below see the findings of independent variables that are statistically significant and have an impact on the number of white residents within the study area:

- Transportation accessibility variables:
  - Distance from the selected block groups located within the one-mile buffer around stations to the nearest rail station in the study area (LnDis2station) shows a negative correlation with the change in number of white residents within the study area. As the distance from rail transit station increases, the change in number of white residents decreases. This implies that the closer to the station, the higher the change in number of white inhabitants. This result confirms the findings of most of the previous studies that indicate that proximity to rail transit stations has a positive relationship with the number of white residents (Farrow; 2001; McKenzie, 2013; Pollack et al., 2010). In addition, the findings of the comparisons between the station area and non-station areas show a major decline in the number of blacks within block groups in south Dallas and block groups within downtown Fort Worth, while there is a major increase in the number of white residents and housing values within the same block groups. This can be attributed to better accessibility generated by rail transit stations.

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- Distance from the selected block groups within the one-mile buffer around stations to the nearest highway access ramp (LnDis2Hgy) has a positive relationship with the change in the number of white residents. This means that the closer to a highway access ramp, the lower the change in the number of white residents. As discussed in the literature, the negative externalities associated with freeways result in the moving away of some residents. Also, a previous conclusion from regression model 1 shows that housing values next to highway ramps are higher in value, so white residents are willing to buy housing units farther away from highway access whose distance mitigates the negative impact of the highway, but where housing value is high enough to attract primarily other white residents.

- Distance to the nearest city downtown (LnDis2Down) from block groups located within the one-mile buffer around stations is associated positively with the change in the number of whites. This means that the greater the distance from the city center, the greater the change in the number of white residents is. This result confirms what have been mentioned in the results of regression model 1 and found in the literature as well. The perception of poorly educated or ethnic-minority residents, traffic congestion, and old homes in the central city have historically played a major role in the movement of highly-educated white residents out of downtowns. Many retailers and businesses followed suit (Frew & Wilson, 2002).

- Socioeconomic characteristics of residents variables:

  - Change in income of residents 16 years and older (LnΔIncom) has a negative relationship with the change in the number of white residents. This means that as the change in residents' income increases, the change in the number of white residents reduces within the study area. The logic behind this relationship is that as the incomes of white residents increase, their demand for a larger single-family home in outlying areas or in luxury areas will increase. So, they will move away from areas next to rail transit stations.

  - Change in the number of residents with at least bachelor's degree (LnΔCollege) and change in employed residents 16 years and older (LnΔEmplyed) are correlated positively to the change in white residents. In other words, the higher the changes in number of college

educated and employed residents, the greater the change in white residents within the study

area. As mentioned in many theories and the findings of previous studies, white residents are

more likely to hold at least a bachelor's degree over minorities. Also, college educated

residents are expected to find better jobs compared to less-educated residents. As a result,

residents with higher levels of education are expected to gain more income, while the

residents with lower levels of education are likely to work in low-paying jobs.

- Change in Hispanic residents (LnΔHisp) has a positive relationship with the change in white

  residents. This means when the change in number of Hispanic residents rises, the change in

  the number of whites also increases. This can be an indicator that white residents do not

  discriminate against Hispanics the same way as they do against black residents and begin to

  accept living in minority neighborhoods. The DFW area is one of the largest metropolitan

  areas for Hispanics immigrant in the United States (Brown & Lopez, 2013). At the same time,

  the educational attainment of these Hispanic residents is improving (Lowell & Suro, 2002)

  and, as a result, their income levels are rising (Krogstad & Flores, 2016). Particularly within

  second generation households, a large number of Hispanic residents are moving from the

  lower class to be middle class. This may be why white residents are more willing to accept an

  increase of Hispanic residents in the same neighborhood.

- Housing market variables:
  - Change in median housing value (LnΔHousvalue) and change in housing rent (LnΔRent) are

    negatively correlated to the change in whites within the study area. This means that as the

    change in housing values and rents increase, the change in the number of white residents

    decreases. The increase in housing values and rents make low-income white residents move

    away from the areas in proximity to rail stations. This may be because the higher cost of

    housing units exceeds the reduction in savings for commuting times and costs generated by

    better accessibility associated with rail transit. Furthermore, higher housing values next to rail

    stations may be encouraging residents to move to outlying areas where they can buy larger

single-family houses and live in neighborhoods with wider streets, lower traffic congestion, minorities, and crimes, and therefore fewer people are living in study area than before.

- Location attributes variables:
  - Change in population density within each block group (LnΔPopDen) is statistically significant and has a positive correlation with the change in white residents. When change in population density is high within a block group, the change in number of white residents will also be greater. This can be attributed to two main reasons. First, many white residents within the study area are middle-class, so they mostly live in smaller housing units or apartments. The other reason is a logical reason—when the number of people increases in block groups, this will result in more white residents within this block group.
  - Change in the number of jobs within the study area (LnΔJob) is positively correlated with the changes in white residents. This means as the change in number of jobs increases within the block groups, the change in the number of white residents also increases. A majority of the residents living within the study area are employed white residents. As a result, those residents may prefer to live in proximity to their workplace and do their shopping within their communities because it reduces commuting cost either by driving only short distance or walking and riding bicycles to their destinations.

6.1.3   Findings and Discussion of Research Question 3

Research Question 3: Do the neighborhoods immediately proximate to rail transit stations experience change in population density for the period between 2000 and 2014? Also, what are the most important controlling factors affecting population density in neighborhoods surrounding rail stations?

The descriptive analysis indicates that the median population density within the block groups located within a one-mile radius around rail stations in the DFW area was around eight people per acre in 2000 and increased slightly to about nine people per acre in 2014. Therefore, the median percent change between 2000 and 2014 is only 1.5%. The number of block groups that experienced a positive percent change was 236 block groups, while 218 block groups experienced a negative percent change. The results also indicate that block groups within the study area did not experience more significant changes

in population density in comparison to block groups in non-station areas. For regression model 3, the findings of independent variables that are statistically significant and have an impact on changes in population density within the study area are presented as follows:

- Transportation accessibility variables:
  - Distance from the block groups located within the one-mile buffer around stations to the nearest rail station in the study area (LnDis2station) shows a positive correlation with the change in population density. As the distance from rail transit stations increases, the change in population density increases, meaning the closer to the station, the lower the change in population density. This supports what Knight and Trygg (1977) suggested four decades ago and still rings true today, that "modern urban transit systems rarely, if ever, provide a significant effective increase in accessibility because the areas served to tend to be already more accessible by auto" (p. 232). In addition, one possible explanation is that within the DFW area, only passenger transit systems are provided for small areas compared to the size of the whole metropolitan. However, even if passenger transit service is more widespread, it is unlikely that the population density would increase next to rail stations—since the DFW area is an automobile-dominated metropolitan area that was mainly developed based on highways constructions. Another possible explanation is that block groups in proximity to rail stations have a higher combined percentage of non-residential uses than residential uses, which decreases the number of people per block group. In 2010, within the block groups surrounding stations, the non-residential uses were around 39.60%, residential uses represent 47%, and vacant land were 13.5% (NCTCOG, 2013b).
  - Distance from block groups located within the one-mile buffer around stations to the nearest highway access ramp (LnDis2Hgy) has a negative relationship with the change in population density. This means that block groups in proximity to highway ramps have higher change in population density than ones located farther away from highway ramps. As discussed in the literature, the improved accessibility generated by highway ramps can play a major rule in increasing property value; therefore, landowners allow higher density (Berry et al., 1963).

- Distance to nearest city downtown (LnDis2Down) from block groups located within the one-mile buffer around stations is associated negatively with the change in population density. This means that the greater the distance from the city center, the lower the change in population density. This implies that the reverse is also true—that the shorter the distance to city center, the higher the change in population density. In general, better accessibility to a city's downtown increases the demand for housing. A city's downtown areas are very densely populated, while suburbs and rural areas are more sparsely populated, with detached houses and small density (Bluestone et al., 2008).

- Socioeconomic characteristics of residents variables:

  - Change in employed residents 16 years and older (LnΔEmplyed) has a positive relationship with the change in population density. This means that as the change in number of employed residents increases, the change in population density increases. Some of the workers are middle-class households, so they live in small homes or apartments. They benefit from better accessibility provided by rail systems, which can help to reduce commuting costs and time.

  - Changes in white residents (LnΔWhite) and Hispanic residents (LnΔHisp) are correlated with the change in population density positively. In other words, the higher the number of white or Hispanic residents, the higher the population density within the selected block group. As mentioned earlier, some of the residents within the study area are middle class, white or Hispanic workers, who live in smaller housing units or apartments. They may prefer to live in proximity to rail stations due to the lower housing value, and to avoid traffic congestion and reduce the commuting costs to their works.

  - Changes in the poverty level of households (LnΔPoverty) is associated positively with the change in population density. The higher the change in poverty status, the higher the change in population density. This is because poor residents usually live in neighborhoods with a high number of housing units that are very small and cheaper in value (Galle et al., 1972).

- Housing market variables:

- Change in median housing value (LnΔHousvalue) is positively correlated with the change in population density within the selected block groups. This means that as the change in housing value increases, the change in population density increases. The results of this study confirm what theories and literature have found. In theory, landowners are willing to compensate the higher land price, so they permit higher density by allowing many housing units on each parcel of land (Berry et al., 1963). In the study area, most of the neighborhoods that experienced higher value in housing units are divided into small units or developed as a multi-family development, which increases the number of population in block groups.

- Location attributes variables:

  - Change in the number of jobs within each block group (LnΔJob) has a negative correlation with the change in population density. This could be an indication that block groups that have higher number of jobs are low in population density. In effect, substantial commercial, office, and industrial use can consume more land within the study area, resulting in a lower percentage of residential uses, thereby lowering population density.

  - Neighborhoods next to rail transit stations that have been developed as a transit-oriented development (Dum_TOD) have a significant positive impact on the change in population density. This means that block groups that have developed as TODs are denser than the block groups that were not developed as TODs. This is consistent with the argument that neighborhoods improved as a TOD tend to have moderate to high density, as a TOD is designed to be denser than the other areas. Therefore, it has more housing units per acre.

6.2 Findings Summary

The major purpose of this study is to examine the relationships between the distance to rail transit stations and the changes in housing value, racial make-up, and population density between 2000 and 2014 within the block groups located within the one-mile buffer (study area) around passenger rail stations in the Dallas-Fort Worth metropolitan area. Thus, this study compares the changes in economic, social, and spatial aspects of the block groups within the study area between 2000 and 2014 and then compares these changes to the changes of the rest of block groups within the four counties served by

passenger rail transit systems. After that, regression models were employed to examine the research questions. Data were collected from many sources and analyzed by different techniques such as ArcGIS and SPSS to answer the research questions.

The comparison results show that the changes in median housing value are greater in block groups within the study area compared to block groups within non-station areas. In addition, the change in number of whites grew far faster within the study area than non-station areas. However, the changes in number of total population and population density has shown a greater increase outside the study area, especially in several outlying areas, while the changes in number of people within the study area has grown only slightly. Furthermore, the changes in number of blacks, Hispanic, college graduated, employed residents, and the number of jobs per block group are greater in non-station areas than in the study area.

The basic results of the regression models show that with the shorter distance to rail transit stations, the change in housing value decreases, the change in population density decreases, and yet the change in number of white residents increases, after controlling for other factors. Interestingly, while proximity to highway access ramps is associated with higher change in housing value and higher change in population density, the change in number of white residents actually decreases within these block groups. The shorter the distance to city downtown, the greater the decline in the change in housing value and the change in number of white residents, even though there is an increase in the change in population density. Within the study area, change in residents' income does not seem to have a significant effect on change in population density, although it does have a positive impact on change in housing value and a negative impact on change in number of white residents within the selected block groups.

The increase in change in college educated residents positively affects the changes in housing value and number of white residents, but this variable was not included in the change in population density regression model since it was not expected to affect population density. The variable for the change in number of employed residents was included in the three regression models. It is insignificant for the change in housing value model, but has a significant and positive relationship with the change in

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the number of white residents and the change in population density. The variable for the change in number of black residents was included in two of the regression models, the change in housing value model and the change in white residents' model. Most studies and theories about housing markets show a negative impact on housing value with the increase in the number of black residents, and this study supports these findings. However, in the change in white residents model, the change in the number of black residents variable is not significant at any level and it does not have any impact on the change in the number of white residents next to rail stations. Interestingly, while the change in number of Hispanic or Latino residents does not have a significant effect on the change in housing value, the greater change in Hispanic or Latino residents does lead to an increase in both change in white residents and population density within block groups located within the one-mile buffer around stations.

As the change in number of jobs increases within the selected groups, change in housing value and change in number of white residents goes up, but the change in population density goes down. The neighborhoods developed as TODs show a positive impact on changes in housing value and population density, but this variable is insignificant in the change in white residents' model. The availability of park and ride facilities has a negative impact on the change in housing value, but it does not have a significant impact on the change in population density. Proximity to amenities was only included in the change in housing value regression model; the findings suggest that the change in housing value rises in proximity to shopping malls and declines next to schools. The distance to parks does not have any significant impact on the change in housing value.

In short, proximity to rail transit stations influences changes in housing value, race of residents, and population density. However, distance to rail transit stations is not the only contributing factor. The impact also depends on many other factors such as transportation accessibility (e.g. proximity to highway access ramp, proximity to downtown), socioeconomic attributes of residents (e.g. income, education, employment, race, ethnicity), and the attributes of the locations (e.g. population density, TOD, park and ride facilities).

6.3 Policy/Planning Implications

This research study provides a useful addition to the existing literature and represents a contribution to the field of urban planning in general and transportation planning in particular. It develops empirical evidence that analyzes the relationship between rail transit stations and the housing market, socioeconomic attributes of residents, and spatial factors of the areas surrounding rail stations. Also, the analysis of the results provides a theoretical contribution to transportation planning, especially in the field of rail transit systems.

The findings of this study constitute a theoretical contribution to the transportation planning field. Many scholars assert that a half-mile radius is the appropriate distance to capture the impacts of rail transit stations on the surrounding area. However, the findings of this study suggest that the impact of rail transit stations should expand to a one-mile buffer or even more. Expanding the buffer to one mile is a better way to understand whether these rail stations increase accessibility for residents living farther away from the transit, which in turn will increase the number of transit riders.

This study concludes that proximity to rail transit stations affect changes in housing value and population density negatively, while a positive impact is shown on the change in number of white residents. The decline in the changes in housing value and population density next to rail stations indicates a lower demand and a lower preference for properties next to rail transit stations. In addition, it is worth mentioning that only very few residents living next to rail transit stations commute by rail transit. Only 3,731 persons out of the total population of the study area (651,212 people) commuted to work by rail transit in 2014 (U. S. Census Bureau, 2015), while the average weekday ridership on rail transit was above 100,000 monthly in 2014[8]. As a result, urban planners and policy makers should suggest some solutions for increasing housing value, increasing population density, and attracting a more diverse population to the study area. This can be done through some strategies that would bring about more success for rail transit systems in the DFW area, increase the transit ridership, and sustain station area development.

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8 North Central Texas Council of Governments (NCTCOG), "Average Weekday Transit Ridership," Accessed 1 April 2017, available at http://www.nctcog.org/trans/data/gasprices/Gasoline_Initial.asp?id_measure=2.

Based on the findings of this study, the most important policy recommendation is that policymakers should promote TOD development to capitalize on creating compact, mixed-use, high density, walkable urban forms, and improve the affordability of housing in neighborhoods adjacent to rail stations. In addition, policymakers should support future transit stations by adopting transit-supportive land use policies that support higher density clusters, mixed-use, walkable communities, and a concentration of activities, rather than supporting low-density communities that stimulate sprawl patterns which in turn increase the dependency on automobiles.

Developing stations as TODs can attract more development to the station area, which also can be considered a positive externality since it can outweigh nuisance, lead to more economic growth, and increase the density within future rail stations in the outlying areas. City urban planners should promote TODs through certain procedures such as by rezoning industrial uses, warehouses uses, and vacant land, and redeveloping projects located in proximity to rail stations in zones that allow higher density such as mixed-use developments and multi-family residential zones. Also, they can promote TOD developments through various development incentive-based programs, such as government funding, facilitate permission and rezoning processes, density bonuses, property tax abatements, affordable housing credits, and free waivers.

Regional and local governments should develop affordable housing for people in need in proximity to rail stations. Developing TODs could serve different groups of people. Thus, providing affordable housing in the TODs can improve the accessibility for transit dependent residents from different races and classes, and in turn increase transit ridership, facilitate commuting to work, and provide improved access to many amenities for diverse groups of people.

Developing communities in proximity to rail stations as TODs can be achieved by promoting a contemporary urban design and facilities such as the station location, parking lots, streets, edges, pedestrian trails, and station plaza. The ideal urban design of a TOD can increase access to transit, encourage transit ridership, which in turn reduce automobile dependency (CMAP, 2008). City planners can impose regulations related to zoning and site planning guidelines that can require developers to follow urban design guidelines provided by the cities and cover all aspects related to transit station areas.

Some externalities related to proximity to rails stations negatively affects housing value, population density, and the number of various residents within these areas. Policy makers and urban planners should give more attention to negative externalities associated with rail transit systems to mitigate negative impacts. Most of the previous studies found that bus stops, streets, and parking lots next to rail transit stations induce traffic congestion. In addition, rail stations increase crime rates in neighborhoods located in proximity to stations. This in turn affects the desirability of living in proximity to rail stations and discourages neighborhoods from welcoming transit stations in proximity to their area. Policymakers, city planners, and transit agencies should work together to make transit stations more attractive to residents who want take advantage of this alternative mode of commuting. They should employ some strategies to alleviate traffic congestion in the area surrounding rail station. Moreover, more parking lots in proximity to rail stations need to be constructed, since it can widen the impact of rail station and attract more riders. However, transit planners need to develop some strategies that make parking lots accessible to transit riders only and curb the potential crimes that these areas attract. There should be an increased police presence in parking lots and areas surrounding rail stations. Increasing station security can also play a significant role in deterring crimes. Not only the station and surrounding facilities should be secured, but also the policing should extend to the close neighborhoods. The decline in crime rates near rail stations and in their surrounding neighborhoods would be an effective marketing tool to attract more residents to live next to rail stations and to convince people living in outlying areas that rail transit will not produce more crimes if it extends to their area in the future.

Rail transit systems in the DFW area run through many multi-centered urban areas, so, urban planners and decision-makers should adopt policies that encourage preservation and redevelopment activities and to infill development in neighborhoods surrounding rail stations, especially if stations are located in proximity to CBDs. Redevelopment activities such as gentrification, urban renewal, and infill development can enhance the economic growth, solve problems of urban decay, and help central business districts to retain its primacy in the urban hierarchy. Local redevelopment authorities can help redevelopment projects by providing a source of funding for these programs and their implementation. In addition, public agencies can offer a combination of incentives and undertake the process of

redevelopment, securing funding, and sustaining daily operation. Also, they will have to make sure that gentrification increases the diversity of these areas, does not lead to any displacement of low-income residents, and achieves social equity goals.

In addition, the improvement of rail transit coverage and transit quality a major factor in increasing transit ridership. Residents sometimes avoid commuting by rail transit since they perceive it to be unsafe, inconvenient, uncomfortable, and unreliable (Litman, 2015). In addition, Cao, Mokhtarian, and Handy (2009) added that the service level, transit frequency, and trip fare are the most significant factors that negatively affect rail transit ridership. Accordingly, transit agencies and decision makers should consider a policy of improving quality of rail transit systems services within the DFW area. This means these systems should cover a large area, provide better service, have shorter waiting times, have more frequent services, and have greater speed.

Above all, the DFW metropolitan area can be considered as an auto-oriented environment where public funds are mostly directed toward highway improvements. Accordingly, an improvement in transit access and quality needs to be incorporated into regional and local policies and other implementation measures that will keep this improvement as first in order. Adopting such polices would make rail transit the best choice for residents as long as it is safe, secure, comfortable, fair, fast, and competitive with private automobiles. In addition, highway and parking policies that support building more roads and parking lots should be limited to make policy makers search for other patterns of development that support an alternative to commuting by automobiles and increase the transit ridership.

6.4 Limitations and Future Research

This research is an excellent opportunity for the generation of future studies. This research represents a first step toward understanding the economic, social, and spatial impacts of rail transit on neighborhoods surrounding rail stations. In the DFW area, more studies are needed to enable more detailed understating of the rail transit stations impacts with the other controlling factors that may increase or decrease the impacts.

This study only focuses on the evaluation of the impact of rail transit stations on changes in housing value, race of residents, and population density within block groups located in proximity to the rail

stations. Future studies can break down housing units by type, meaning to single-family and multi-family housing units when investigating the impact of proximity to rail stations on housing prices. Also, future studies should use a survey of the households instead of block groups to determine whether or not these property types result in a more thorough evaluation of proximity to rail stations. Using small units, like parcels, could also result in more accurate results. Block groups give the median housing value for all housing units within the selected block group, but using parcels helps to account for different types of land use, such as residential (e.g. single, apartments, or condominiums), commercial, office, or vacant land. In addition, if a researcher uses parcels, he can consider what falls within a selected radius, while some housing units may fall out of the buffer if the block group unit is used. Additional research is needed to investigate the changes in commercial, retail, and office property value, which represent about 32% of the study area. County appraisal districts can help to find the needed data related to those non-residential uses.

Regarding population density, this study only looks into the impact of rail transit stations on population density (number of residents per acres), which leaves out the net residential density (number of residents per the size of the residential area), and employment density, which are significant issues to investigate. Therefore, future studies should keep track of net population and employment density trends within the areas next to rail transit stations over a long term to better understand the dynamics and mechanisms of factors affecting those types of densities in the area adjacent to rail stations.

Most studies in the United States investigate the impact of rail stations on housing units located in proximity to rail stations. These studies concluded that these areas are more desirable and have higher value, and that therefore the areas next to rail transit stations are denser. However, this study shows the opposite results. Housing units that are too close to stations may experience some negative externalities resulting from rail transit systems. So, some of the future studies need to use more than one buffer around rail stations; for example, a future study can use four buffers around rail stations (e.g. 0-¼, ¼-½, ½-¾, ¾-1 mile) or extend the radius to two miles and divide it to four rings. Also, future studies should more carefully measure the nuisance effect (e.g. noise and traffic congestion) resulting from the rail stations and lines. They should also measure the crime rates next to stations. Accordingly, measuring

these negative impacts can be helpful in identifying some methods to reduce the magnitude of these negative impacts.

This study investigates the differences between block groups within a one-mile radius of rail stations between 2000 and 2014, which can be considered a long time. However, the analysis takes place during a period of economic crisis that effected the economic activity in the United States. Further studies should be done when the economy of the United States returns to its usual healthy growth and is more stable. These studies can use more recent data such as 2011-2015 American Community Survey or Decennial Census for 2020—when they become available.

Additional research can examine the impact of better urban design of rail stations and surrounding areas (e.g. street furniture, landmarks, edges, plaza, bicycle and pedestrian trails) on housing value and socioeconomic aspects of residents. Ideal urban design elements can increase the attractiveness of locations, which in turn positively affect property value and rail transit ridership. In addition, future studies should try to include in regression models some of the independent variables that are not as readily available, such as the number of crimes within the study area. Crime rates, in particular, are one of the major factors affecting housing markets and socioeconomic attributes of residents next to rail transit stations.

Lastly, passenger rail transit agencies in the DFW area are planning to extend the rail transit in the near future. In 2003, rail transit agencies and NCTCOG decided to add eight passenger rail corridors throughout the DFW area (NCTCOG, 2003). Further studies should investigate the impact of rail stations within these proposed corridors and on the adjacent neighborhoods, and compare the impact between the existing and proposed rail stations.

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