LINKING JOB/HOUSING BALANCE, LAND USE MIX AND COMMUTE TO WORK

A Dissertation

by

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ABSTRACT

With gas prices rising rapidly, many people have started to believe that it has become imperative to reduce their vehicle miles travelled. Land use patterns have been found culpable of contributing to the extra VMT driven by the average. As such, urban planners have employed many strategies to attempt to reduce this portion of VMT. For example, research shows that smart growth in the form of mixed-use compact development results in a better match of jobs and housing since it brings trip origins and destinations closer, thereby making work trips shorter.

This research uses spatial modeling in GIS and Multiple Linear regression/ANOVA in SPSS to analyze the link between job-housing (J/H) mismatch, land use mix and worker commute flows. The study examines J/H imbalance within a travel catchment area using a 7-mile buffer from the centroid of each census tract in Dallas County, Texas. Moreover, it uses jobs, workers local economic and community data in the form of Local Employment Dynamics, Longitudinal Employer-Household Dynamics and Quarterly Workforce Indicators provided by the US Census Bureau to carry out area profile, area comparison, distance/direction, destination, inflow/outflow and paired area analysis for workers place of work and residential distributions in Dallas county. This analysis is linked in Geographical Information Systems to the land use map, which is classified as an entropy index. The GIS results present a spatial picture of labor-shed, commute-shed, job-housing balanced and imbalanced areas by relating the land use mix and commute flows of workers in Dallas County. Moreover, MLR regression model in SPSS shows that Land use mix, Job/housing balance and housing affordability are significant predictors of mean travel time to work. This strategic tool developed through Target Area Analysis and Hot Spot Analysis will act as a guideline for land use planners to understand the regional growth complexities related to work flows. The analytical model developed can also be deployed to direct land development patterns, which will ultimately improve the quality of life, halt urban sprawl, lower costs to businesses and commuters and produce related positive externalities.

DEDICATION

To my husband Zubair Ali Raja

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NOMENCLATURE

J/H	Job/Housing
VMT	Vehicle Miles Travelled
DART	Dallas Area Rapid Transit
ANOVA	ANalysis Of VAriance
LUM	Land Use Mix
MTT	Mean Travel Time
TAZ	Traffic Analysis Zones
LHED	Longitudinal Employer-Household Dynamics
LED	Local Employment Dynamics
QWI	Quarterly Workforce Indicators
HH	House Hold
GIS	Geographical Information systems
NCTCOG	North Central Texas Council of Governments
JHR	Job/Housing Ratio
HAI	Housing Affordability Index
DART	Dallas Area Rapid Transit
CTPP	U.S. Census of Transportation Planning Package
MLR	Multiple Linear Regression
CI	Confidence Interval
SD	Standard Deviation
SE	Standard Error
Min	Minimum
Max	Maximum
IDW	Inverse Distance Weighting
HBW	Home Based Work

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1. INTRODUCTION

Smart growth, Neo-urbanism, prevention of urban sprawl, Transit-oriented development and Compact development, all these concepts have been in lime light since many decades for the transportation and land use planners, transit managers and operators, real estate developers, public officials and many concerned citizens. However, all of these concepts have two notions in common i.e. the promotion of high density and mixing of diverse land uses. In addition to this, all of the aforementioned school of thoughts share three universal transportation objectives. Firstly, to decrease the number of motorized trips (trip degeneration), Secondly to reduce travel distances/time and thirdly to prevent sprawl and conserve the natural and manmade resources (Cervero and Kockelman 1997). The main issues that have formed the basis of all these professionals come to a mutually agreed solution are numerous. Highway construction and widening has failed to remove traffic congestion although it has been successful in delaying the problem but not removing it altogether. This is supplemented by the wastage of fossil fuels in the country. Moreover, rise in the air pollution levels and clean air acts are pressurizing land use planners and policy makers to find out ways to reduce vehicle miles travelled and time spent on wasteful commute. The land development patterns in America have continued to support personal automobiles for the past many years resulting in edgeless cities, suburban sprawl and many other allied ills (Cervero and Seskin 1995). Among all the trips made, work trips have been the longest (Weitz, Association et al. 2003). As a solution to all this, land use planning through compact development is one promising policy. This is popularly achieved by implementing Job-housing balance and mixing the land uses.

Jobs-housing balance is a land use planning tool that the local agencies have been trying to employ for years so as to get an approximate like number of jobs and households in a jurisdiction (Kain 1968; Weitz, Association et al. 2003). Planners can successfully plan communities with better balance of jobs and housing units, so as to shorten the work trips thus curbing down the Vehicle Miles Travelled (VMT) (Cervero 1989; Ewing, DeAnna et al. 1996; Weitz, Association et al. 2003).J/H balance is not about reducing the number of work trips made rather it is targeted to reduce the distance/time for the work trip. According to research J/H balance reduces the VMT for an area by 15 % (Ewing, DeAnna et al. 1996). This balance changes with the differing levels of land use mix (LUM), job and housing density (Frank 1994).Given the background, this research aims to provide an innovative technique using spatial modeling and regression techniques in GIS to investigate commute to work in job-housing balanced/imbalanced areas in differing levels of land use mix. The selected case study area is Dallas county, the study aims to analyze the work trips made by the residents of this region. This research will identify target areas under the greatest stress of wasteful commute. Moreover, it will help us better understand and manage the complexities related to the J/H mismatch, sustainable land use mix and commuting behaviors. The hypothesis of this research is that, **"Increasing the Job-housing match and land use mix will help decrease the Vehicle Miles Travelled and commute time to work.** Considering this the research lays down a few specific objectives of study.

1.1 Specific research objectives

This study seeks to address the following objectives:

1. To spatially identify the job-housing balanced and imbalanced areas in Dallas county, and identify their type like job-poor housing rich and job-rich housing poor locations.
2. Examine relationships among job-housing imbalance, land use mix and commute to work (both in terms of distance as well as time) by performing spatial modeling in GIS.

3. To check the viability of aforementioned measures in conjunction with socio-economic and travel characteristics of workers as predictors of commute to work, using ANOVA, Curve Estimation and Multiple Linear Regression.

1.2 Research questions

To carry out the purpose of study, the following research questions will be addressed:

1. What is the relation between the job-housing balance and commute to work? what do the current practices in the world and particularly in the United States indicate about this phenomenon?
2. Where are the specific locations of job-housing imbalanced areas in Dallas County? What are the socio- demographic characteristics of workers belonging to these areas? What is their travel behavior, where they work? Where they live?
3. How the commute to work is affected by different settings of LUM and J/H match, controlling for the socio-economic and travel characteristics of workers?

1.3 Significance or justification of research

With the fuel prices getting sky-high it has become mandatory to reduce VMT, land use planners have employed many strategies to play their role in bringing down wasteful commute. These strategies include infill housing and brownfields strategies, parking reductions, Transit-oriented development, tax credits and mixed use development etc. Research shows that high density and mixed use development result in an adequate job-housing balance (Institute 1999; Weitz, Association et al. 2003). Smart growth in the form of high density mixed use compact development results in a better match of jobs and housing (Cervero 1989). Compact development is the key solution to most of the urban land use & transportation problems. It is believed that people in high-density mixed use developments will make shorter trips and travel less than residents of other areas. Land use patterns (i.e. the separation between residence, work places and other destinations) have been blamed for about one third of the enhancement in driving (Weitz, Association et al. 2003). Studies have revealed that access to the work is most conducive in an environment of high density and mixed land use (Cervero 1989; Cervero 1991; Levinson 1998; Boarnet and Crane 2001). Moreover literature has also proved that these mix of land uses brings trip origins and destinations closer for people and will change their travel patterns (Steiner 1994). This reduces congestion and decreases the VMT (Frank and Pivo 1994; Ewing, DeAnna et al. 1996), it also minimizes the air pollution levels in an area (Armstrong, Sears et al. 2001). Likewise a better J/H balance also slows down the increases in the housing costs over time (Council 2000). Furthermore, it lowers down the infrastructure costs like highway expansions and its associated improvements (Cervero 1989; Cervero 1991; Armstrong, Sears et al. 2001). Thus it is important to investigate mismatches between jobs and housing present in an area. This J/H balance strategy is an efficient method to enhance local transportation and regional growth goals as well. Additionally, research in this area will help policy planners to halt urban sprawl and better manage the scarce urban land and its allied infrastructure costs. Finally, it will help stop commuters wastage of time/cost in longer distances to work and its associated inconvenience caused to them.

The expenses and advantages of contrasting land development and transportation investment practices have been the topic of considerable debate in the literature (Frank 2000), Although it is previously proved that there is a positive correlation between high density, mixed land use, job housing balance and VMT, the gap in the available literature still remains. As the relationship between urban design and travel behavior is complex (Joh, Boarnet et al. 2008) there are further directions towards this issue that need to be explored. While many urban planners have adopted J/H balance as a policy-tool to manage geographical growth of urban regions and a strategy to reduce traffic congestion in the American cities, the relationship between job-housing and commute patterns still has little empirical evidence (Sultana 2002), the kind and extent of the relation between the two is still a myth. Furthermore, there is still considerable debate on the real definition of J/H balance, its relation with the commuting patterns, traffic, VMT, vehicular congestion and air pollution (Cervero, 1989a; Deakin, 1989; Giuliano, 1991). The earlier studies have mostly examined job-housing balance by employing quantitative techniques to compare different modes used to travel across socio-economic characteristics of the workers. This research is versatile, and is an addition to knowledge, because it uses ANOVA, curve estimation analysis and MLR to analyze job-housing mismatch and its link with the Land use mix (LUM).Although a large body of knowledge concludes that compact, mixed-use development can reduce VMT by varying means and amounts usually contingent on the fact as to where the study area is situated but still Empirical data on explicit design features functional in different scenarios affecting VMT are lacking and verifiable scientific evidence is still missing. Thus in order to get rid of uncertainties, it is significant to carefully conduct and monitor new research to better understand the benefits and costs of compact, mixed-use development policies. A transportation research analysis of driving and its relation with the built environment discovered five areas requiring further research and examination. **Changing housing plus travel preferences was one of those target research areas needing in depth investigation** (Gomez-Ibanez and Humphrey 2010).

1.4 Limitations of the research

Personnel preferences including attitudes and travel behavior are likely to be influenced by the built environment over time (Kenneth Joh 2008). J/H balance is also affected by these factors, where you work and where you live, are very complex questions, however this research does not take into account the choices of people to select/prefer a residence or a neighborhood they choose to live in. The six-category formula put up by Frank (2006) has some limitations as well, the chief one being the “missing land” issue, i.e. the land uses missing from the 6 category formula for e.g. the industrial land use may alter the entropy score but this category is ignored/absent in the formula and may adversely affect the true land use character score of the area.

1.5 Dissertation outline

Section 1 is the introductory part which starts with problem identification i.e. the Job-housing imbalance and gives a detailed background of processes leading to this issue. Then the chapter moves towards the statement of purpose, the major goals and objectives, the scope & benefits of study and finally it discusses the limitations of the research being conducted.

Section 2 is the review of the relevant literature. This section starts with the in-depth definition of job-housing imbalances, discusses its kinds and major typologies. Next it discusses the J/H imbalance and land use connection. After that it runs through the past studies that have been conducted in the field both in the US and worldwide so as to know what other experts in the field have done already and how the current research builds over their work and in what way it challenges the study results of a few. Thus this chapter gives the most current knowledge in the topic under discussion and addresses methods others have used and what refinements to their processes are being done in this dissertation.

Section 3 introduces the study area i.e. Dallas county. This chapter explains the major socio-economic, travel and land use characteristics of the study area. It further specifies the extent of problem existing in the area and identifies the types of J/H imbalances at different locations within the county and what are the travel characteristics of people in these communities. It also includes the description of the project, the work plan and data sources to be used. As this research uses GIS to investigate J/H imbalance and links it to land use characteristics, this chapter gives detailed conceptual-spatial model to be deployed and describe how this innovative tool can be used to solve the issue in an optimal way. Furthermore this chapter describes the main hypothesis, dependent and dependent variables to be used during regression analysis in SPSS.

Section 4 is the LHED, LED and QWI data analysis part of the dissertation; this displays the generated maps and explains how they have been generated? What techniques have been employed? What they show? What they mean? The whole Analysis helps us to get a better picture of wasteful commute in Dallas County.

Section 5 is the calculation and analysis of Jobs/housing Ratio. This elaborates the procedure, results and conclusions of GIS and ANOVA analysis on the census data of Dallas County.

Section 6 is the calculation and analysis of the entropy scores for Land use mix in Dallas County. This chapter provides the details of the mathematical formula deployed in our GIS model and enlists the procedure, calculation and interpretation of the findings on our analysis.

Section 7 is the Multiple Linear Regression Analysis. It lays down the hypothesis to be tested. Provides the explanation of dependent and independent variables, gives the results of the model including R-squared, F-statistic, P-value and the interpretation of the MLR coefficients. Finally it enlists the details of model sensitivity tests.

Section 8 is the target area analysis. It gives the insights to the overlay analysis performed in GIS using spatial analyst tools. The findings present a spatial picture of areas under the greatest stress score of Job/ Housing mismatch, least mixing of land uses, longer work commute times and housing unaffordability measured together.

Section 9 analyses the work trips made by public transit (DART data).Inverse Distance Interpolation have been performed in GIS using geospatial analyst tools to explore the characteristics of trips made by DART riders and to relate them spatially with LUM and J/H variables. Finally Analysis of Variance tests are applied to check the link between these built environment characteristics and workers commute by transit.

Section 10 encapsulates the research findings and discusses them in detail. This section extracts useful information in the form of results which will further help land use and transportation planners in decision making related to urban growth and transportation issues. This chapter summarizes our coefficients, R-squared and P-values for the regression we will run in GIS and explain their elucidation and implication. Moreover, it presents in a condensed form the innovative tools/techniques applied to unveil landuse transportation interaction factors and guides as to how the same can be used by urban planners/related professionals to resolve the current issues related to wasteful commute. Furthermore, it contains recommendations inferred from the results so as to guide the policy makers/economists/politicians/urban professionals/land developers to better tame urban growth, help placement of diverse land uses and related transportation policies. In addition to this, it defines areas open for further research related to the topic under discussion.

2. LITERATURE REVIEW

Understanding the access to work and land use interaction is again another challenge. It is proved by a number of research works that everything going about the land use has its related transportation repercussions and vice versa each transportation action affects land use (Frank 1994; Cervero and Seskin 1995; Ewing, DeAnna et al. 1996; Cervero and Kockelman 1997; Chen 2000; Frank 2000).As such, in most of the regions of United States workers have made housing choices which have contributed towards increased travel times and distances. Today the workers of an employment centre are more disbursed than ever before. This is leading to lower densities and decentralization of employment. (Sφφt, Berman et al. 2010). Although it is well accepted that increased and matched job opportunities near neighborhoods improve the employment status and lowers the commute times, but the issue is mainly the absence of available matching income and housing parity. According to a study, half of the counties in Chicago region are net importers of workers (Sööt, Berman et al. 2006). Table 1 below gives an overall account of commuting flows in the US regions.

Table 1.   Commuting flows in US metropolitan areas

Suburbs to central city	18,175,489	17.4%
Within suburbs	40,745,878	39.0%
From suburbs to outside home MSA	7,650,705	7.3%
Central city to suburbs	7,984,014	7.6%
Within Central city	27,425,079	26.3%
From central city to outside home MSA	2,402,466	2.3%

(Source: US. Census Bureau 2006)

The work force is becoming more mobile thus increasing inter county trips and travel times, this is a serious threat to the functionality of public transportation and self containment of regions. Table 2 indicates an intimidating fact that the average commute time has gone up to 25.3 minutes in 2010 as compared to 22.4 in 1990s.

Table 2. U.S. workers by commute time, 1990, 2000 and 2010

Commute time	**1990**	**2000**	**2010**
Less than 15 minutes	15.9%	30.1%	28.1%
15–29 minutes	51.6%	36.3%	36.5%
30–39 minutes	14.7%	15.7%	16.3%
40–59 minutes	9.0%	10.7%	11.1%
60 minutes or more	5.9%	7.3%	8.0%
Average travel time (minutes)	22.4	25.5	25.3

Sources:

1990 - U. S. Department of Transportation, Volpe National Transportation Systems Center, Journey-to-Work Trends in the United States and its Major Metropolitan Area, 1960–1990, FHWA-PL-94-012, Cambridge, MA, 1994, p. 2-6.

2000 - U.S. Bureau of the Census, Journey to Work: 2000, Tables 1 and 2, 1990-2000, March 2004.

2010 - U.S. Bureau of the Census, 2010 American Community Survey, Tables S0802 and B08303.

Moreover, the increase in home ownership whereby, workers are buying houses which are affordable and suitable to them but are mostly far off from their work place is also a contributory factor towards wasteful commute. Hence most US workers are participating in the much debated tradeoff between housing and transportation expenditure by moving to the edge or suburbia and increasing the commuting distance by the usage of personal vehicles (Soot and Sen 1979).

2.1 Workers tradeoff housing and transportation costs

The basics of how workers tradeoff between housing and transportation expenditure takes us back to the "Bid rent theory" given to as by William Alonso**,** the hypothesis states that "*Housing and commuting are bundled "goods," with households who face a fixed budget continuously trading off one for the other according to their incomes, demographic characteristics, and lifestyle preferences. Some households opt to live far out on the metropolitan fringes preferring bigger homes and lower housing costs, but at the expense of higher commuting costs and times. Stereotypically, these include young families with modest incomes and children. Other households choose to live closer to urban centers and, correspondingly, more job opportunities. The shorter commutes they enjoy also come at a price: higher housing costs per square foot of living space"*.(Alonso 1960; Alonso 1964; Alonso 1968a; Alonso 1968b; Alonso 1971; Alonso 1976; Alonso 1980; Alonso and Starr 1987). Figure 1 gives the commute time for single-person HH, married couple HH and household with children versus housing cost per room.

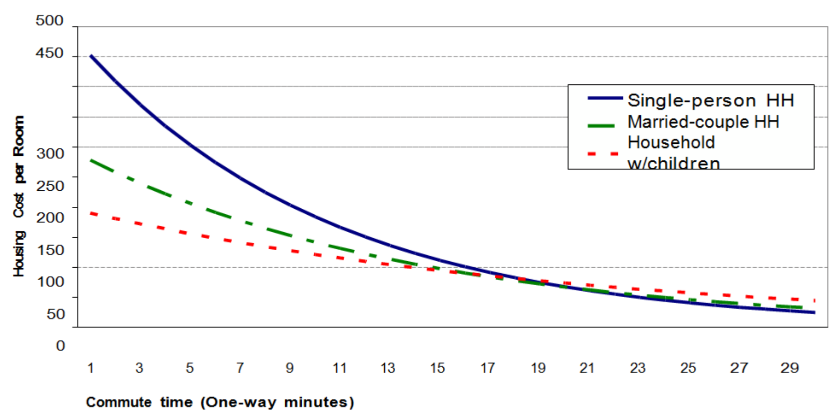


Figure 1 Graph showing commute time vs. housing cost per room

(Source: Alonso and Starr 1987)

Americans spend a bizarre proportion of their incomes on housing and mostly negate the associated transportation costs of living and commuting from the suburbs. According to The Bureau of Labor Statistics, 2004 Consumer Expenditure Survey one-fifth of American households, spend 52.6% of their income on housing and transportation combined. Amongst the income classes, Wealthier households have more housing and transportation choices as compared to the other income groups in terms of both quality and degree, so they choose the most convenient and advantageous neighborhoods. Apart from income, household type also plays its role here working families (pre-dominantly those with children) mostly favor to live in affordable places but in places like Atlanta and Dallas–Ft. Worth they have chosen to live in the suburbs where the houses are expensive and transit services are also scarce. However tough may be the case still 88% of American households possess or have access to at least one personal vehicle i.e. they have the financial ability to own and maintain a car (Cervero, Chapple et al. 2006), this makes Americans adopt a lifestyle which is anti-transit friendly and packed with wasteful commute (Refer to Figure 2). This practice is in contrast with that of compact smart-

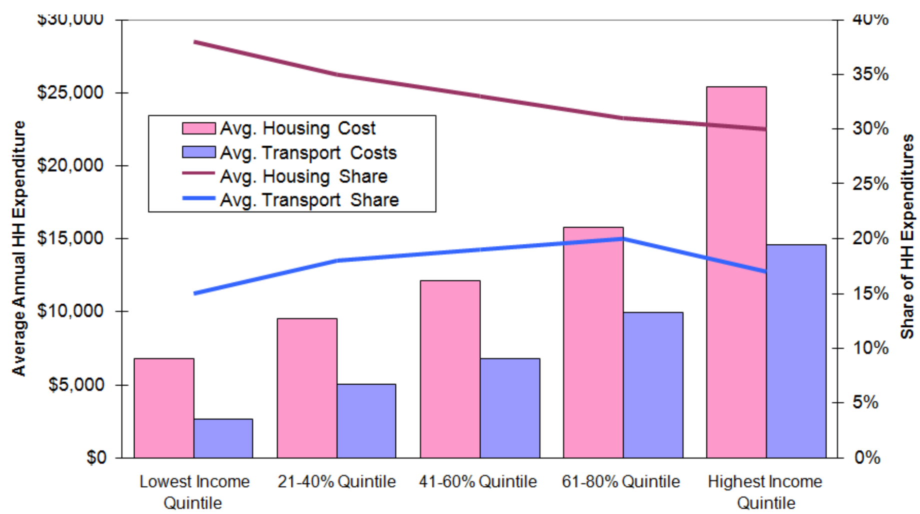


Figure 2 Average yearly housing & transportation costs & burdens by income quintile

(Source: Bureau of Labor Statistics, 2004 Consumer Expenditure Survey)

growth setting and promotes urban growth that ignores land use mixing and J/H balance policies. Thus the responsibility of most of the ills related to wasteful commute is associated with this urban sprawl. The chief one being the congestion on roads and burden on the allied infrastructure. Whereby, congestion is principally considered a consequence of work commute, implying spatial mismatch of the workplace relative to the location of housing. (Horner and Murray 2003). This mismatch is described in detail below:

2.2 Job-housing balance

A recent definition of J/H balance states that, "*It is a provision of an adequate supply of housing to house workers employed in a defined area (i.e., community or sub region). Alternatively, a jobs/housing balance can be defined as an adequate provision of employment in a defined area that generates enough local workers to fill the housing supply. The definition of an area can be stated in terms of an optimal "commute shed" around employment centers that conforms to expressed commuter preferences about home-to-work commute distances"* (SCAG 2001).The concept of J/H balance was initially floated by Cervero (Cervero 1989). Since then it has been much into debate and most researchers, policy analysts and environmentalists support the idea as an efficient tool to reduce commute time and distance.

It is not easy to define the J/H balance, earlier assumptions were made to keep a ratio of one job to one household to create the match but with growing economic stress more than one worker living in a single household has made things more complex. Thus, J/H balance now refers to the roughly equal distribution of employment prospects and workers living across a geographic area. In other words J/H balance occurs *"when both the quality and the quantity of housing oppertunities match the job oppertunities within an area"* or *"Provision of an adequate supply of housing to house workers employed in a defned area*" (SCAG 2001). Thus it is the provision of employment in an area that produces sufficient local employees to fill the housing supply. This trend has been studied along many diverse directions by various researchers (Kain 1968; Bookout 1990; Cropper and Gordon 1991; Giuliano 1991; Hamilton, Rabinovitz et al. 1991; Cervero and Landis 1992; Giuliano and Small 1993; Wachs, Taylor et al. 1993; Ihlanfeldt 1994; Levinson and Kumar 1994; Wu 1994; Cervero 1995; Cervero, Rood et al. 1995; Levtnson and Kumar 1997; Peng 1997; Levine 1998; Levinson 1998; Cervero, Rood et al. 1999; O'Regan and Quigley 1999; Chen 2000; Shen 2000; Wang 2001; Horner 2002; Sultana 2002; Clark, Huang et al. 2003; Horner and Murray 2003; Breheny 2004; Horner 2004; Muñiz and Galindo 2005; O'Kelly and Lee 2005; Ong and Miller 2005; Yang and Ferreira 2005; Cervero and Duncan 2006; Greenwald 2006; Horner and Mefford 2007; Song, Wang et al. 2007; Marion and Horner 2008; Yuemin 2008; Meng, Wu et al. 2009; Wang and Chai 2009; Loo and Chow 2011; Zhao, Lu et al. 2011).

J/H match can be measured through many quantitative measures including jobs-to-housing ratio, jobs-to-occupied-housing-units ratio, percentage of workers residing locally, employment to population ratio and jobs to resident labor force etc. However, Job-housing ratio (JHR) is the most widely used measure to evaluate this; it is simply the number of jobs divided by the number of housing units in the area of analysis. This ratio is assumed to be ideal if ranges between 1.3: 1 to 1.7: 1(Ewing, DeAnna et al. 1996) or according to other researches 1.4:1 to 1.6:1 (Cervero 1991). However, some researchers have also used a range of 0.75:1 to 1.5:1 as balanced J/H ratio in their studies (Sultana 2002) and others declare that a jobs to household ratio that considerably fluctuates from the 1.0 to 1.29 standard, can be categorized as out of balance (SCAG 2001). A jobs to employed residents ratio can also be used, which is best at 0.8:1 to 1.25: 1(Cervero 1996). These numbers are based on the assumption that there are approximately 1.5 workers in each household. Nevertheless, debate is still underway as the researchers continue to argue on a single fixed standard for JHR to be used as the best one (Cervero 1996).

Many studies have observed the link between commute to work, J/H balance, land use mixes and residential preferences. Some of them have also used the concept of "wasteful commute", "excess commute" and "minimum commute" to check an area to fulfill these interrelated metrics (Small and Song 1992; Buliung and Kanaroglou 2002; O'Kelly and Lee 2005; Ma and Banister 2006; Ma and Banister 2006; Charron 2007; Yang 2008; Layman and Horner 2010), revealing that a large portion (about 40-60%) of a regions commuting may be designated as excess (Horner 2002). Consequently, changing urban form by job decentralization and improving the access to work have become important topics of debate and a necessity towards sustainable urban transportation system.(Loo and Chow 2007; Loo and Chow 2011). This can be achieved through J/H match in central city areas (Macek, Khattak et al. 2001) as well as in the suburbs.

Levine (1998) studied residential location preferences for the workers using discrete choice model of residential location, the results indicate that commute time is the most important determinant making this decision. Presence of inexpensive housing near employment centers can effect residential location and choice specifically for low-to-moderate-income, single-worker households. As such under some circumstances, their policy implications do not result in decreased congestion levels (Levine 1998). Cervero's gravity model (1989) explaining relationship between job-housing and regional mobility reveals intense correlation between congestion on freeways and job-housing mismatch. Moreover in his study of job-housing imbalance in the metropolitan Chicago and San Francisco he concludes that the residential choices are governed by factors like work places within close proximity, housing costs etc (Cervero 1989). According to another study, a 10% increase in the number of jobs in a single occupational group within a 4 mile buffer of one's residence is associated with a 3.29% decrease in VMT (Cervero and Duncan 2006).

A study analyzing the commute behavior in Dallas- Fort worth, Texas, finds that spatial factors are significant in explaining commuting behavior, they better explain travel times as compared to explaining travel mode and trip chaining. Result of the study propose that land use strategies like new urbanism and jobs-housing balance, would be viable practices in the regions around employment locations (Shin 2002). Moreover, U.S. Environmental Protection Agency (EPA) promotes J/H balance by calculating the Smart Growth Index 2.0; through this they determine the ratio of employment to population in a jurisdiction, which they call the "Diversity Indicator". A study carried out by them found that doubling the indicator gives a 5% reduction in VMT plus 6% reduction in vehicle trips for residents living and working in the areas analyzed (USEPA 2012).

A GIS analysis conducted by Sultana (2002) assesses the job/housing imbalance within a travel catchment area using a 7-mile buffer from the centroid of each Transportation Analysis Zone for Atlanta metropolitan area with 1990 U.S. Census of Transportation Planning Package (CTPP). The study confirmed job-housing imbalance as the most important determinant towards longer commutes to work and recommended placing high quality housing near job-rich locations in order to save and economize workers commuting time (Sultana 2002). However this study did not look into the type of relationship between J/H balance and mean travel time to work. Furthermore, education level, gender, age, mode of travel and other such demographic explanatory variables were also not considered for regression analysis. . Likewise a research using GIS with CTPP 1990 to analyze differences of travelling in Chicago at the Traffic Analysis Zone (TAZ) level, results in a model that explains 50% of the variation of commuting in 7,835 TAZs defined by J/H balance ratio, distances from the CBD and sub centers etc. (Wang 2000). Another study implying GIS to investigate the link between jobs-housing ratio and urban commuting found a non-linear relationship among the J/H ratio, VMT and trip distance in the metropolitan area of Portland, Oregon,. However, a JHR lower than 1.2 or larger than 2.8 indicated noticeable changes in VMT (Peng 1997).

On the other hand a group of professionals also believes that J/H balance has little to do with commute times, traffic congestion, residential preferences and atmospheric issues (Giuliano 1991; Giuliano and Small 1993; Wachs, Taylor et al. 1993; Peng 1997). Residential considerations are complex and the choices mostly depend on neighborhood characteristics, types of schools in the vicinity, nearby leisure activities, crime rate, quality of construction of houses, road conditions etc. They argue on the significance of J/H balance as a public policy to curb the travel time to work. According to a research the link between where people live and where they are employed is very complex, and job access is a weak determinant of these choices. The J/H balance is a usually a product of urban development process and not that of a deliberate public policy. Thus jobs-housing balance is not a useful solution for transportation and related air pollution concerns (Giuliano 1991). Similarly a research applying geographical information system (GIS) techniques to analyze the trip length of workers of Portland Oregon metropolitan area concluded a non-linear relationship amid the jobs-housing ratio and Vehicle Miles Travelled. VMT noticeably changed with J/H balance just in case when the J/H ratio was less than 1.2 or greater than 2.8 (Peng 1997). An Australian study analyzing commuting distance by occupation for Sydney Metropolitan Area of New South Wales challenges the US studies by declaring that J/H ratio is an inadequate measure of urban form effecting VMT and workers commute is better explained by factors like occupational prestige, education and weekly hours of work (Watts 2009). Wacha and Taylor (1993) compared commuting patterns and residential preferences for thirty thousand employees of a health care provider in Southern California. It is a longitudinal analysis using time-series data, which synthesized the employee records for a period of six years and survey responses from 1500 workers. The study identified that workers residential location preferences include the quality of neighborhood, schools and the associated perceived safety risks besides the work-home separation but their research found meager evidence to validate the case that jobs-housing imbalance amplifies travel distance and time (Wachs, Taylor et al. 1993). Guiliano and Small have also concluded almost the same findings in their study of commuting time for Los Angeles, California, whereby they found that although a statistically significant relation exists between Job-housing imbalance and increased travel time but there are several other dominating factors contributing to it (Giuliano and Small 1993).

Although, the advocates of neo-urbanism, smart growth, sustainable development etc have claimed that all these strategies help support J/H balance to reduce VMT and travel time but the studies have not been able to adequately prove the link between the above mentioned measures. Prevailing research on land use and travel did not clearly support or invalidate these claims adequately due to lack of data and methodological limitations (Kenneth Joh 2008). Thus the argument is still on, researchers have conflicting views about the relation. As such we find many debates, some in the support of job-housing balance as a useful strategy to lower VMT and some against that, this calls for further research in the area.

2.2.1. Background to the problem

There are a number of reasons which contribute to the job-housing mismatch, these are summarized below.

a. Decentralization/suburbanization

This phenomenon is most common in America and is becoming increasingly popular whereby the workers work in the downtown or the core areas and live far away in the suburbs/edge cities owing to a number of reason including better amenities, peaceful living, quality of houses, safety factors, cost of living and many other such factors.

b. **Fiscal and exclusionary zoning**

Rigid segregation of land uses allows single land use to exist at a place this usually results in undersupply of housing near work places, public and retail offices, commercial establishments etc. Similarly exclusionary zoning does not offer housing for all income groups and specifically the lower income group suffers, leaving them with little choice to select housing from. As such the procedure forces people to travel longer distances towards their place of employment and to fulfill their everyday needs.

c. **High rents and housing costs**

Increased costs associated with buildings and their rents, around the work place, makes the workers to live far, pushing several service employees out of the local housing market.

d. **Demographic trends**

Some of the demographic trends also increase the job-housing mismatch e.g. the intensification of dual wage-earning households and career swings.

e. **Personnel preferences of the Americans**

Americans have always given weightage to better housing and amenities in and around the residential locations and neglected the associated transportation and environmental costs. It is not a matter of some individuals but it is the matter of culture. Long commutes for better housing quality have become a norm of the nation. However, the whole US society is now paying the price of making such kinds of housing choices. This has given rise to the concept of "wasteful commute" whereby people are undergoing more VMT than required.

2.2.2 Typology of jobs-housing balance

Jerry Weitz (2003) devised a typology of jobs housing imbalanced areas (Weitz, Association et al. 2003). In his book "Job Housing Balance"(2003) he has categorized J/H mismatched areas in to four types:

Type 1: These are the edge cities or the suburban employment centers. Here we have too many low-paid jobs and little low-cost housing.

Type 2: These are the downtown employment areas. Here we have highly paid jobs but very little luxurious housing with all the amenities.

Type 3: These are the older suburbs and central city neighborhoods. The jobs are mostly high wage and majority of the housing is towards the low-end.

Type 4: High income bedroom communities. These have very fine costly housing and high rents but just a few high wage jobs.

These J/H balanced and imbalanced areas are more clearly explained by Figures 3 and 4 below.

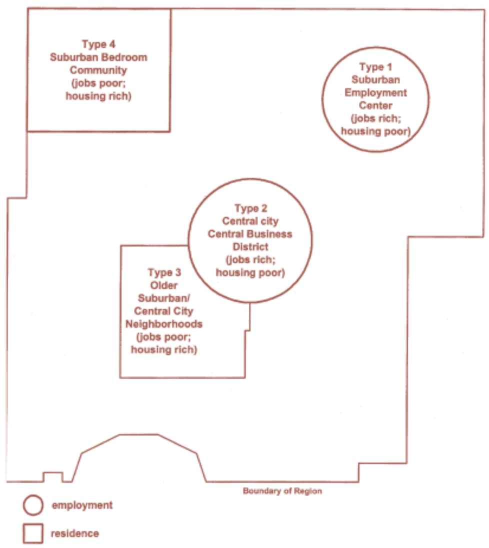


Figure 3 Four Types of j/h imbalanced areas in a region resulting in longer commutes

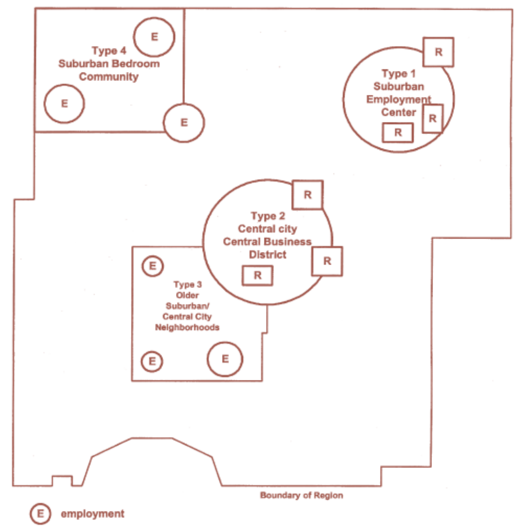


Figure 4 Balanced distribution of j/h shorten commute trips

(Source: Weitz, Association et al. 2003)

Therefore, J/H balance is now used as a policy tool by many local and regional authorities to curtail urban sprawl. As an example, the "*Incentive Grant Program*" is one of the type of inclusionary housing plans in California (Calavita and Grimes 1998). In the year 2001 this program offered $25 Million as grant funding to the qualifying cities and counties of California, to increase housing supply in the region and was followed by the Workforce Housing Reward Program in 2004. The basic aim of these programs was to reward the local agencies for improving the housing production. Moreover, the statewide compliance rate towards these programs reached to 78% in 2006 (Jacobs, Mandell et al. 2007) and are growing thereafter.

2.3 Job-housing balance and the LUM connection

Nevertheless, there is more to J/H match as a policy tool to bring down the VMT, according to professionals J/H balance and mixed use development are complementary planning strategies (Cervero and Duncan 2006). Both of these policies act as effective tool to bring down wasteful commute. Mixed land use was very common type of urban growth category until the US environment entirely changed with the advent of rigid Euclidian zoning, which had its origin based on the fact that landuses should be separated so as to save the residents from the noxious gases of industries, noise and traffic of commercial uses etc but with the passage of time this proved wrong and studies revealed greater health problems related to segregated landuses like reduced walking, obesity and greater automobile pollution. On the contrary, mixed use has been revealed as a chief ingredient required to shore up walking and more greener modes of travel (Brown, Yamada et al. 2009).

A special report on driving and built environment encourages the mixing of land uses to improve the access of housing to jobs. The analysis suggest a combination of land use policies including density, mixed-use, job-housing and other supportive demand measures that make substitutes to driving relatively more suitable and inexpensive. The major obstacles towards this being the restriction on mixing of land uses especially in the suburbs this is further affected by political motives of landowners who have their personnel interests. Thus the opportunity to improve the condition lies in new housing construction and near transit corridors. Zoning regulations must be relaxed for these areas as public infrastructure investments in combination with development incentives can help achieve the right J/H balance land use mix.(Gomez-Ibanez and Humphrey 2010). Zoning policies should be reevaluated in job-rich areas and vacant areas (designated to any use) lying near to them should be changed to residential uses. This will allow workers to live close to where they work (SCAG 2001). However, the report still underestimates the explanatory powers of urban form to predict VMT. As a response to the report, a meta-analysis by Ewing and Cervero suggest that the new Five D's of urban form are powerful predictors of VMT (Refer to Table 3).

Table 3 Weighted average elasticities of VMT with respect to 5D variables

Variables		**No of Studies**	**Weighted Avg. elasticity of VMT (e)**
Density	Households / pop density	9	-0.04
	Job density	5	0.00
Diversity	Land use mix (entropy index)	10	-0.09
	Jobs-housing balance	4	-0.02
Design	Intersection/ street density	6	-0.12
	% 4-way intersections	3	-0.12
Destination Accessibility	Job accessibility by auto	5	-0.20
	Job accessibility by transit	3	-0.05
	Distance to down town	3	-0.22
Distance to Transit	Distance to nearest stop	6	-0.05

(Source: Ewing, Nelson et al. 2011)

Most of the studies reveal that land use mixing, job-housing balance and measures of accessibility (after controlling for the demographic variables) are highly significant factors influencing travel behavior (Cervero 1989; Cervero 1991; Cervero 1995; Cervero 1996; Kockelman 1997). A study comparing the two land use strategies, ‘job-housing match' and 'retail-housing balance' in the San Francisco Bay Area, indicates that proximity of jobs to housing reduces VMT more by a substantial margin when compared to the other approach. This study recommends strengthening the job-housing match policies for California. Research analyzing the relationship between jobs housing in Guangzhou, China proves that increased J/H balance has helped in bringing down VMT and curbing traffic congestion. Moreover, mixed land use should be encouraged and functional zoning should be discouraged to reduce travel distances and time (Zhou and Liu 2010). Another study comparing the commuting length and time between work place and residences, in sprawling Atlanta and self-contained Boston, shows shorter trips and less commuting time in Boston than Atlanta (Yang and Ferreira 2005). A research analyzing job-housing spatial balance in Shanghai, China states that mixed land use contributes significantly to reinforce job-housing spatial balance. The dominance of jobs in the core and housing in the suburbs has increased the spatial mismatch in the city which has resulted in increased levels of average commute distance and time (Yuemin 2008).

However as mentioned earlier, there is a contrasting view as well, there is little evidence on the direct or linear relationship between Job-housing balance and VMT current research suggests that the link between where people decide to live and where they choose to work is complex, and **may be** a weak determinant of job access considerations (Giuliano 1991). Crane (1999) reports that the link between urban form and regional commute behavior is weak, owing to the fact that home-based work trips only account for 16 % of total trips and 20% of total VMT, nationally (Crane 1999).This study investigates the role of "D for diversity" from the 5 D's put forward by Cervero and Ewing, to explain the role of J/H balance and land use mix to predict travel time/distance to work.

3. STUDY AREA, DATA SOURCES AND RESEARCH METHODOLOGY

It is already both scientifically and statistically proved from the literature quoted in the previous section that land use and accessibility affects VMT. In this concern my study aims to examine and analyze the work trips in different settings of J/H balance and LUM. Now moving towards the study area, Dallas County is very interesting as far as its land use mix and population distribution is concerned.

3.1 Overview of study area

According to US Census 2010, population of the county is 2,368,139 with a total area is 871.28 square miles and a population density of 2,718 persons per square mile. Previously, the region had the major development and concentration of uses within the CBD, but with the advent of the new millennium and DART and Trinity bus/rail services

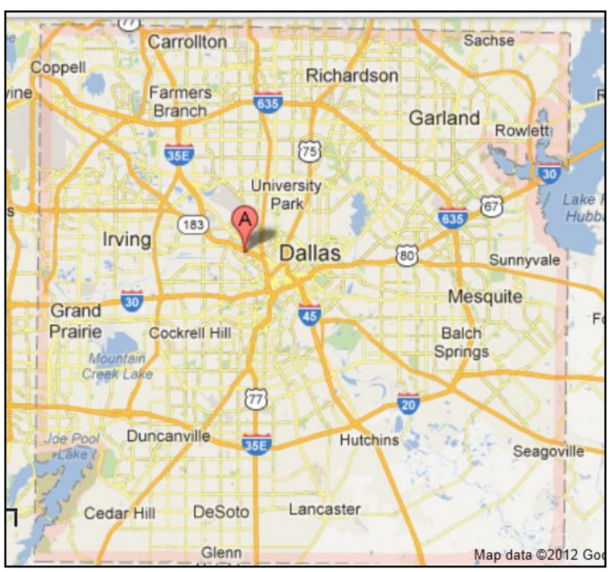


Figure 5 Dallas county map *(Source: Google Maps)*

a pattern of multi nucleus have emerged within the city. The size of the area is so enormous that it does not only revolve around the CBD but also has several suburban Job centers within the region. The city of Dallas forms the major part of Dallas County. Figure 5 shows the Dallas County map showing prominent cities within the area. The key geographical regions are explained as follows:

3.1.1 North Dallas

The North Dallas area is far off from the CBD/downtown but has acquired the shape of a new nuclei attracting high income class. It has neighborhoods which can be classified as the most expensive areas in the county; the region is mostly treated as exurb/suburb of Dallas. There is a lot of commuting between North Dallas and other areas (especially South Dallas), because the growing suburbs cannot survive on their own middle and high income residents (IShikawa 2006). These sub-urban offices need blue-collar low-income workers for housekeeping, cleaning, maintenance labor etc. This cheap labor mostly resides in South Dallas, so there are many people commuting to North Dallas from other parts of the city through DART. Ethnicity wise the whites are more prominent in the North Dallas area, whereas other minority groups have increased noticeably along the newly extended LRT corridor (DART) (IShikawa 2006).

3.1.2 Midtown Dallas

This area contains multi-family dwellings in a mixed use setting. There is an intermingling of offices, retails and other commercial structures, which generate land use diversity. This is a "Transit-oriented development" with the DART Park lane, walnut Hill and Lovers Lane stations forming the hub of activity. It is a sort of an urban village includes Whole foods grocery, office buildings, health clubs and other service oriented industries like salons, dry cleaners and apparel. Additionally it has some residential units, as well. This is an urban setting with layered vertical projects.

3.1.3 UpTown Dallas

This is among the most "new urbanist" areas and contains many walkable neighborhoods; the developments are mostly new happened in late 20th and 21st century, with densely populated areas and pedestrian friendly streets. The vicinity contains a wide variety of land use mix including office buildings, high-rise residential structures, apartment towers, retail buildings, nightlife casinos & pubs, motels, hotels etc. The setting is more urban and its life style attracts the attention of youth and teenagers and has become an urban magnet for them. The setting is quite unconventional when one compares it to the rest of compartmentalized Dallas

3.1.4 Downtown Dallas

'Down Town Dallas' as the name says it all, is the Central Business District (CBD) of the city. It is the geographic centre of the city and is bounded like a ring with freeways and DART lines surrounding it and binding it by a loop. The development inside the ring has a more organic character and aggravated in the early 2000's. The area has eleven districts, high density (4,339/sq mi or 1,673/km2) and is different in form that besides holding different commercial, restaurants, hotels, office, public building and other such uses, it contains lots of residential structures also. The area has undergone many land use changes/conversions; many residential towers and high-rise condominiums have sprung into the area.

3.1.5 South Dallas

This area is relatively scarcely populated; the majority of residents are low income and Hispanic by race. Many huge patches of land are still lying vacant. The land use pattern is quite simple, the major land use type being ‘single family residence’. Major DART stations serving the area are Ledbetter and Westmoreland etc.

3.2 Demographic and socio-economic characteristics

The area is predominantly occupied by whites with about 69% of the total population followed by 22.5% Blacks. Home ownership rate is 54.7% i.e. significantly less than that of Texas (64.8%). Median value of owner-occupied housing units, (2006-2010) is \$129,700. Median household size is 2.75 and median income (2006-2010) is \$47,974. The percentage of persons below poverty level is 17.6%. In 38.4% of the Census tracts the median income is less than US \$40000, 44% have it between US \$40000.1-750000, 13.6% have it between US \$75000.1-130000 and the rest 4% have it above that (US Census, 2010). GIS Maps have been prepared by the author to explain the major variables of use (Refer to Figures 6-14).

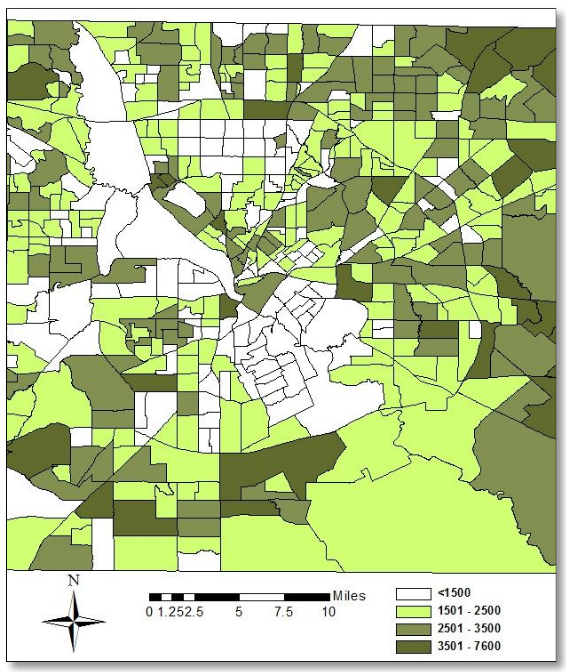


Figure 6 Map of Dallas County showing total number of workers

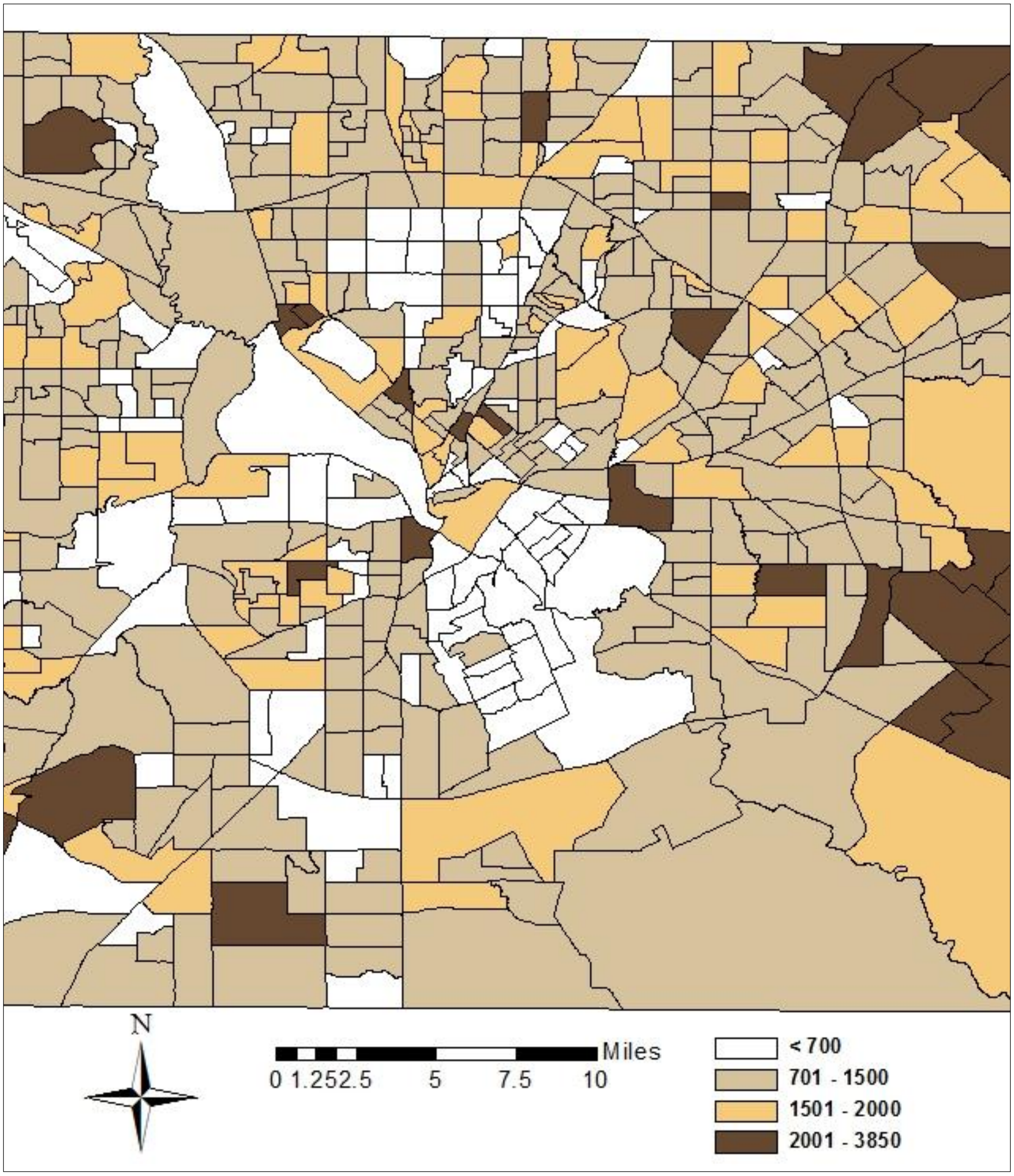


Figure 7 Map of Dallas County showing male workers

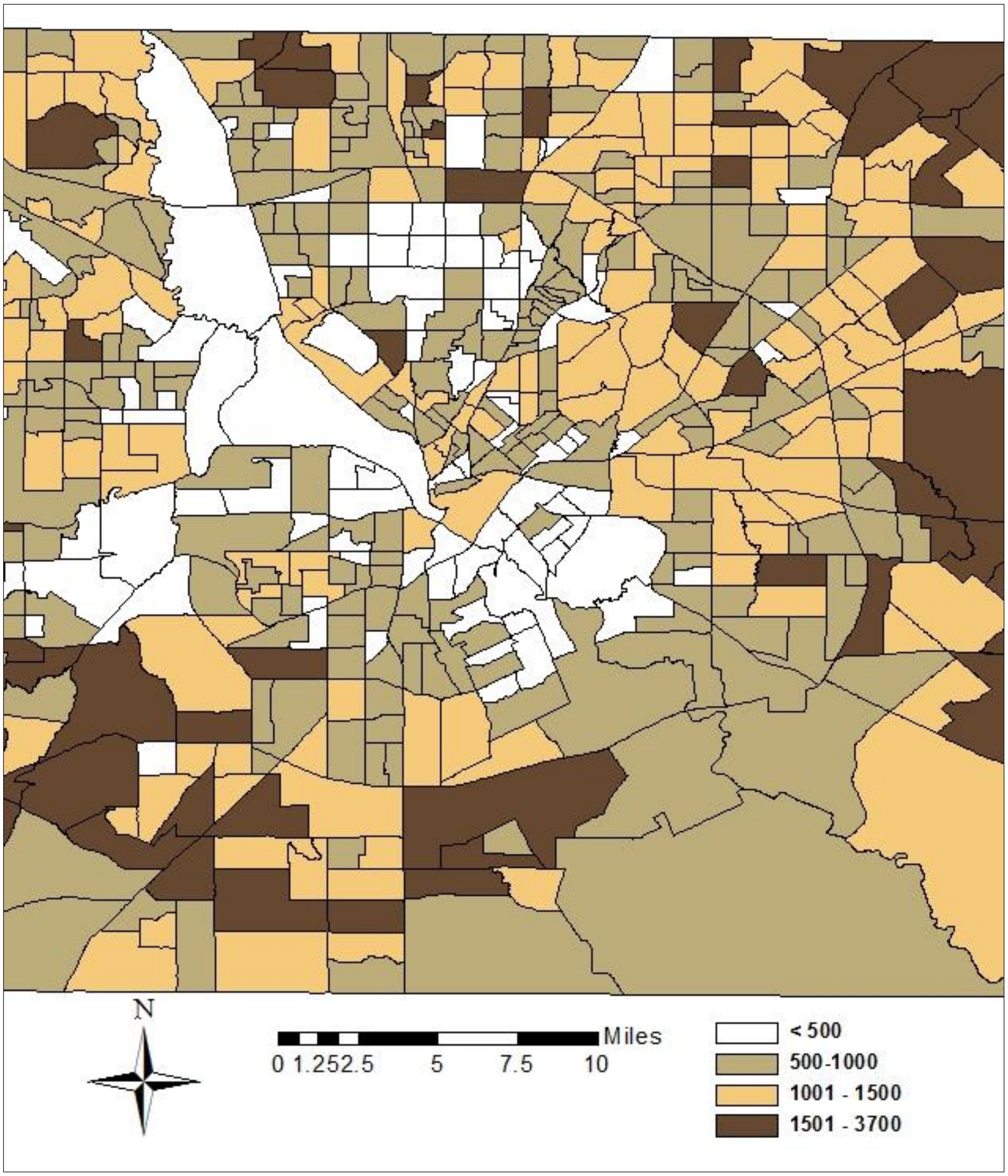


Figure 8 Map of Dallas County showing female workers

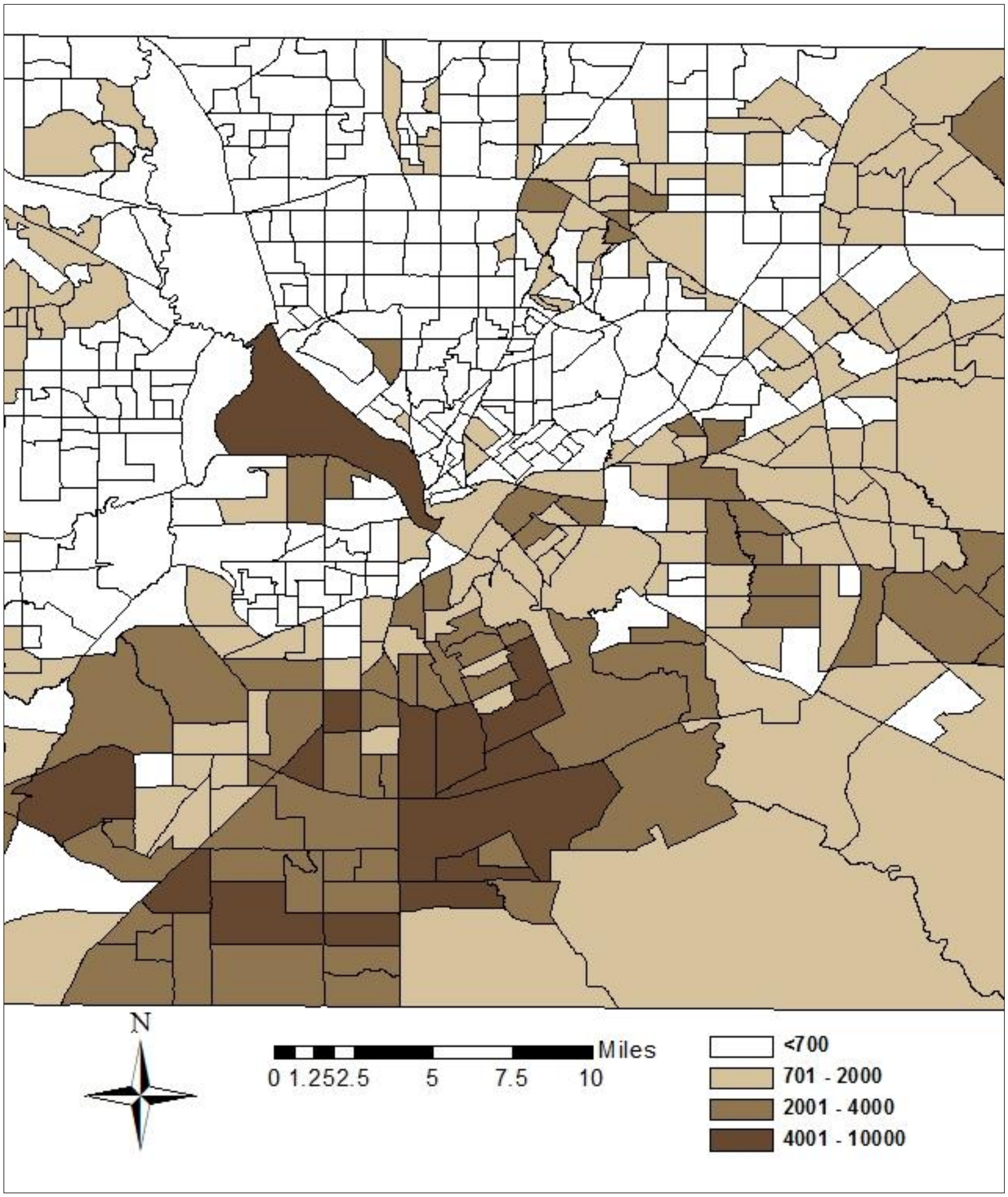


Figure 9 Population of blacks Dallas County

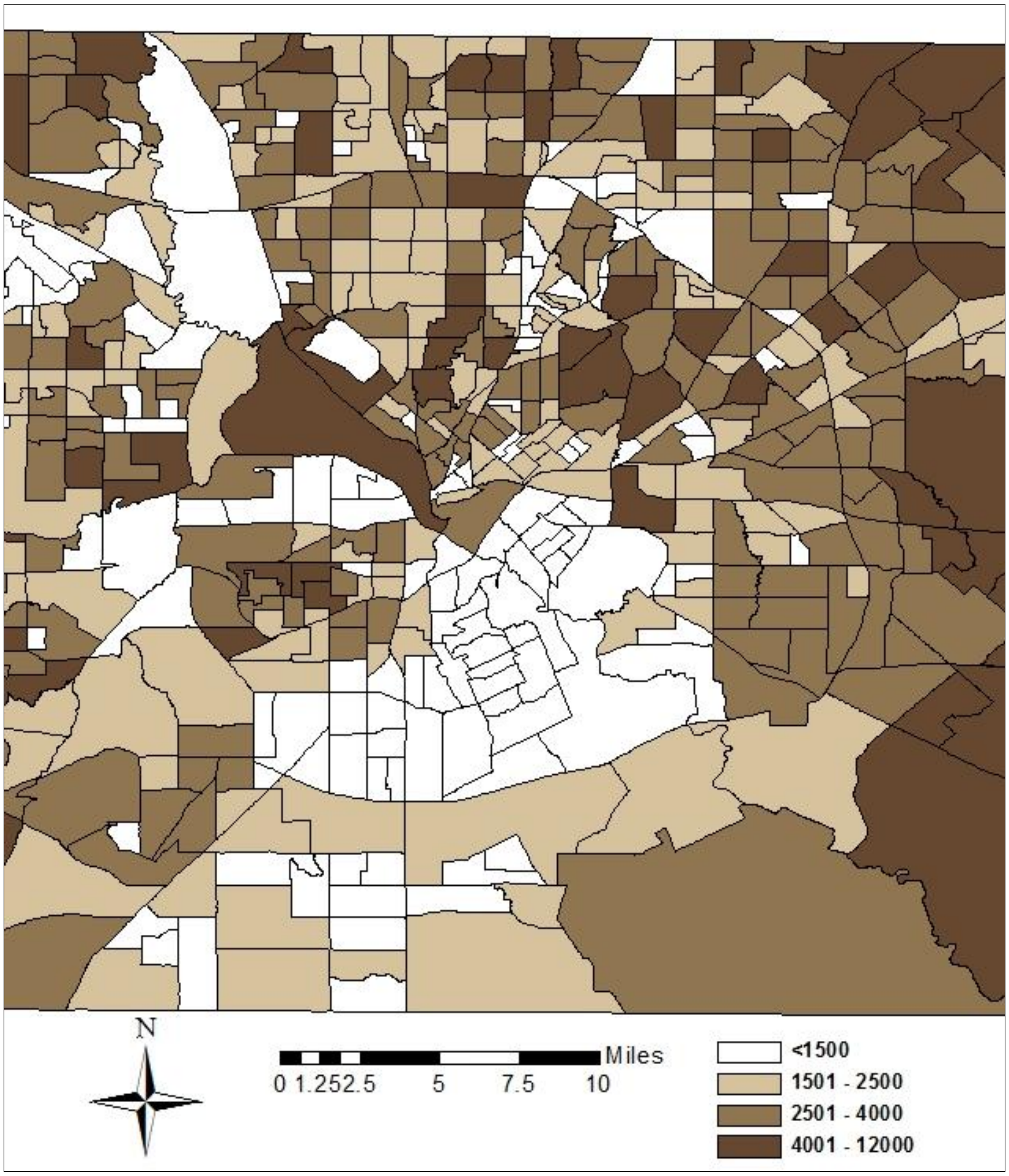


Figure 10 Population of whites Dallas County

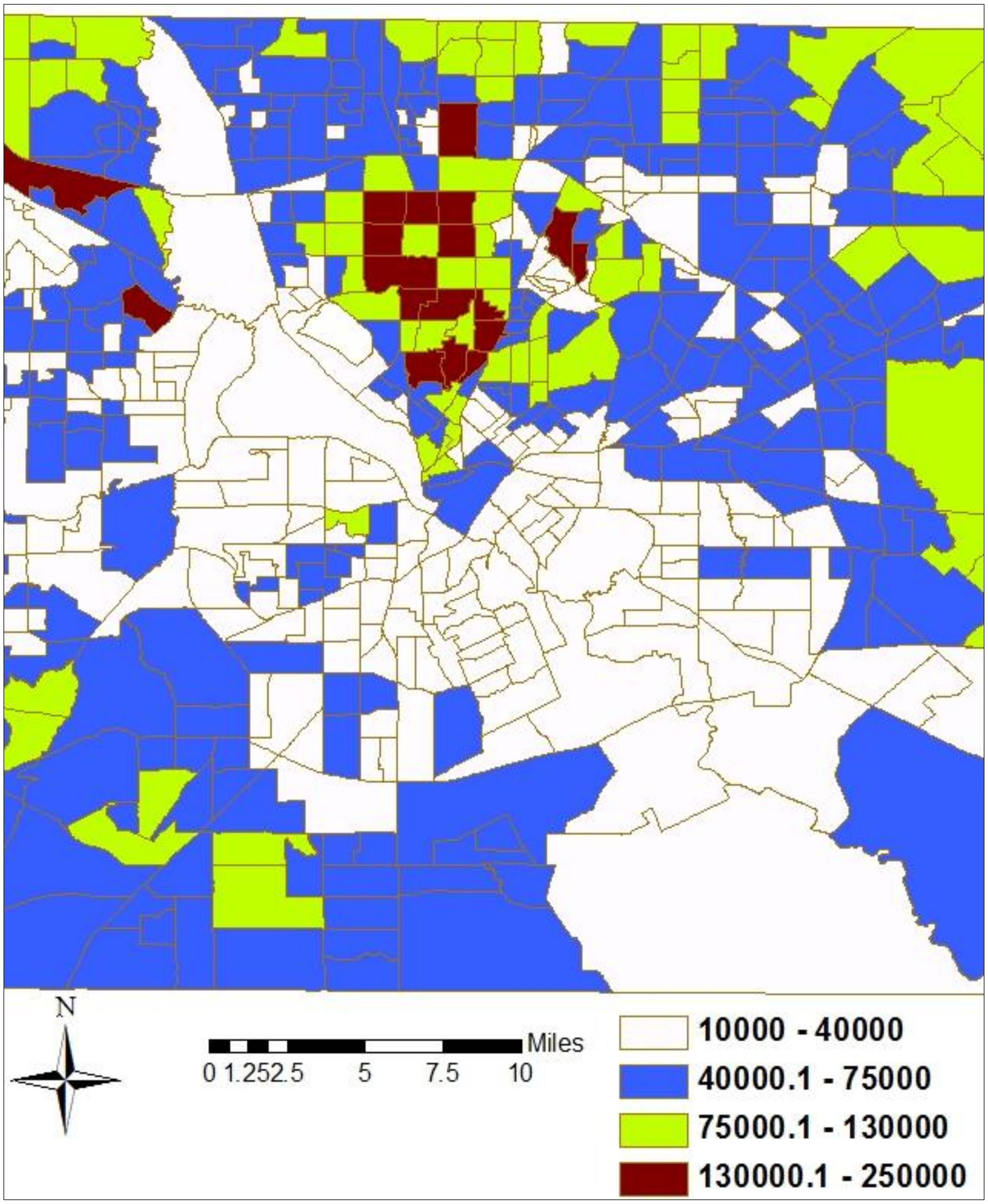


Figure 11 Median income of residents (2010)

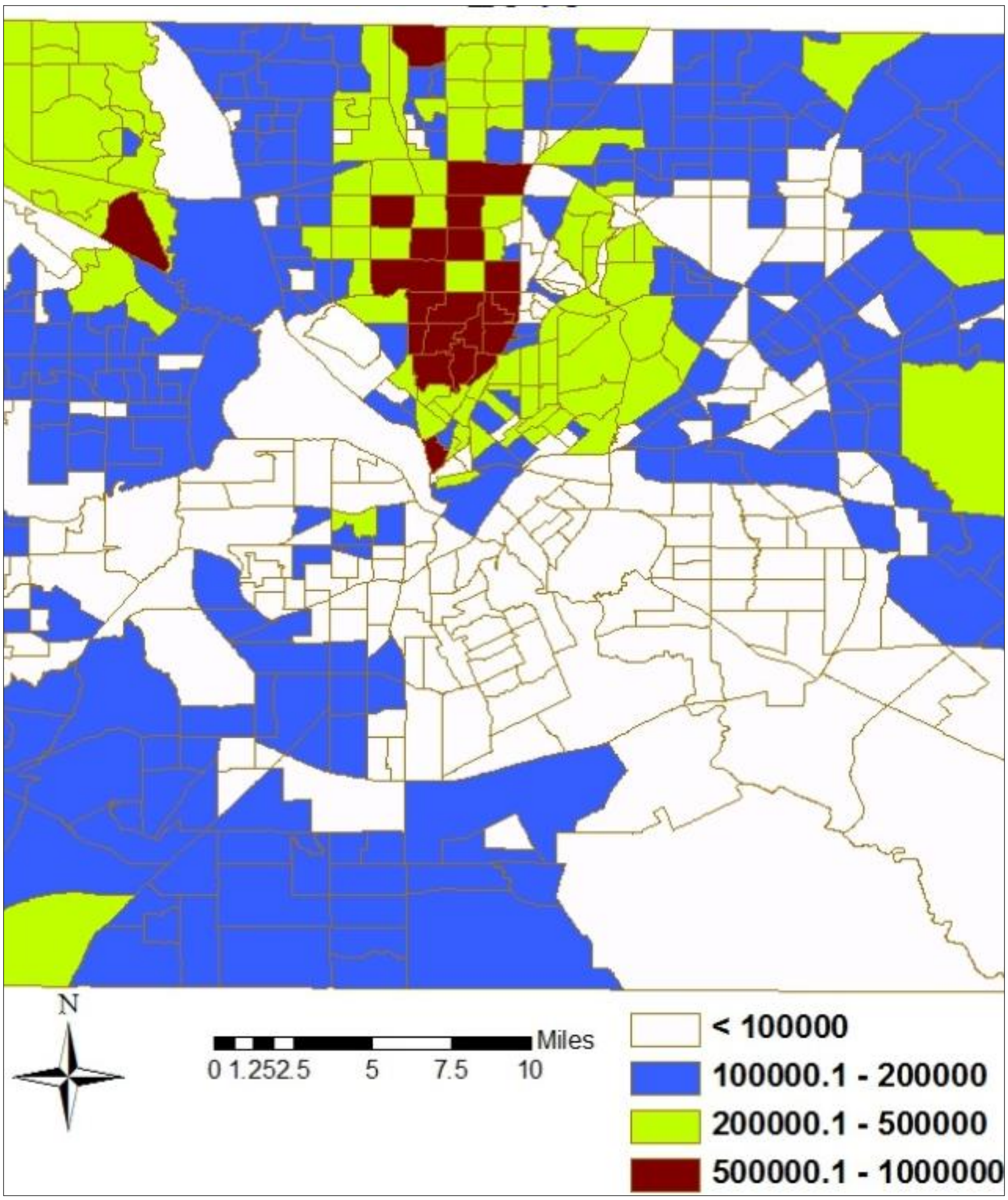


Figure 12 Median value of houses (2010)

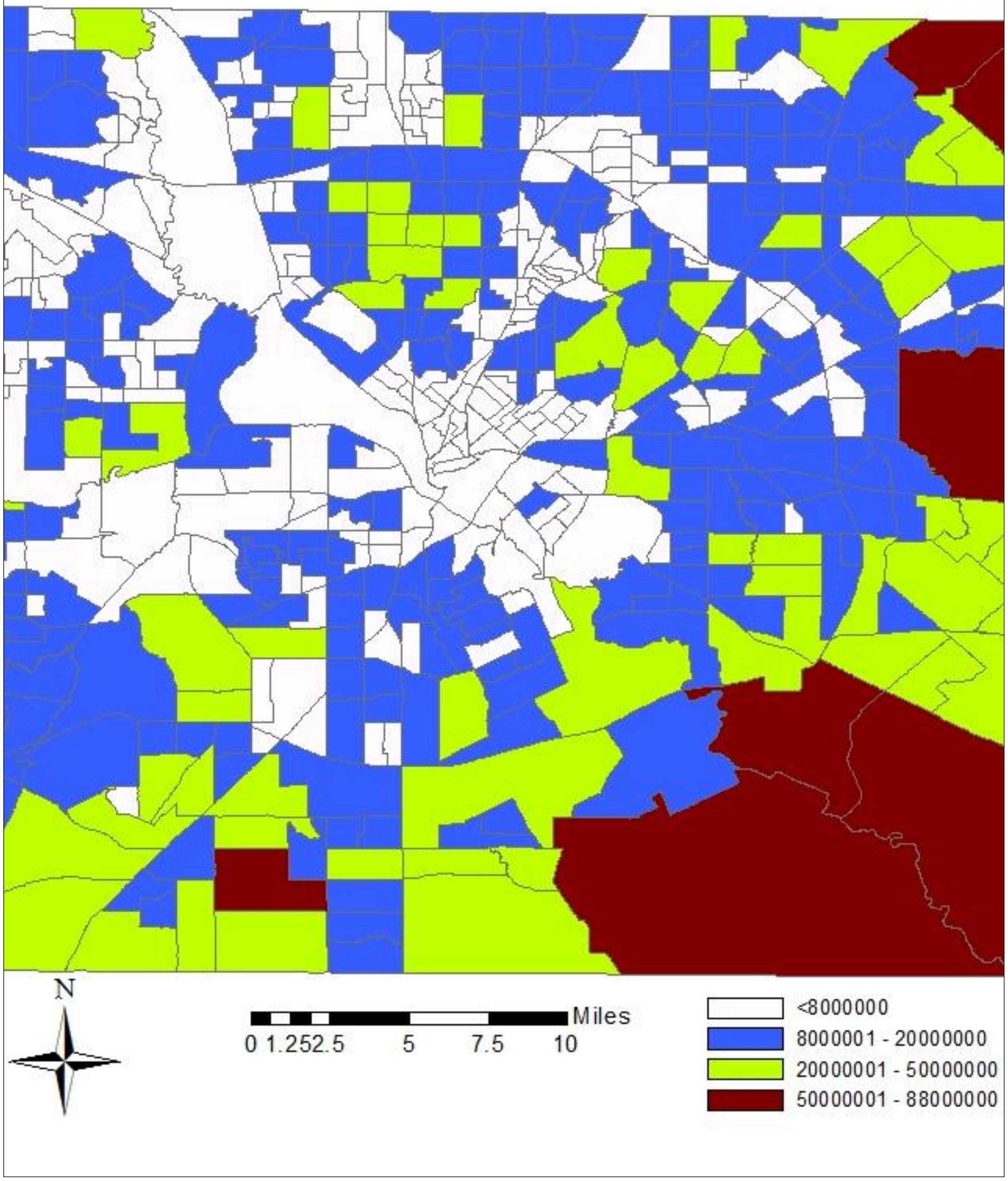


Figure 13 Single-family residences

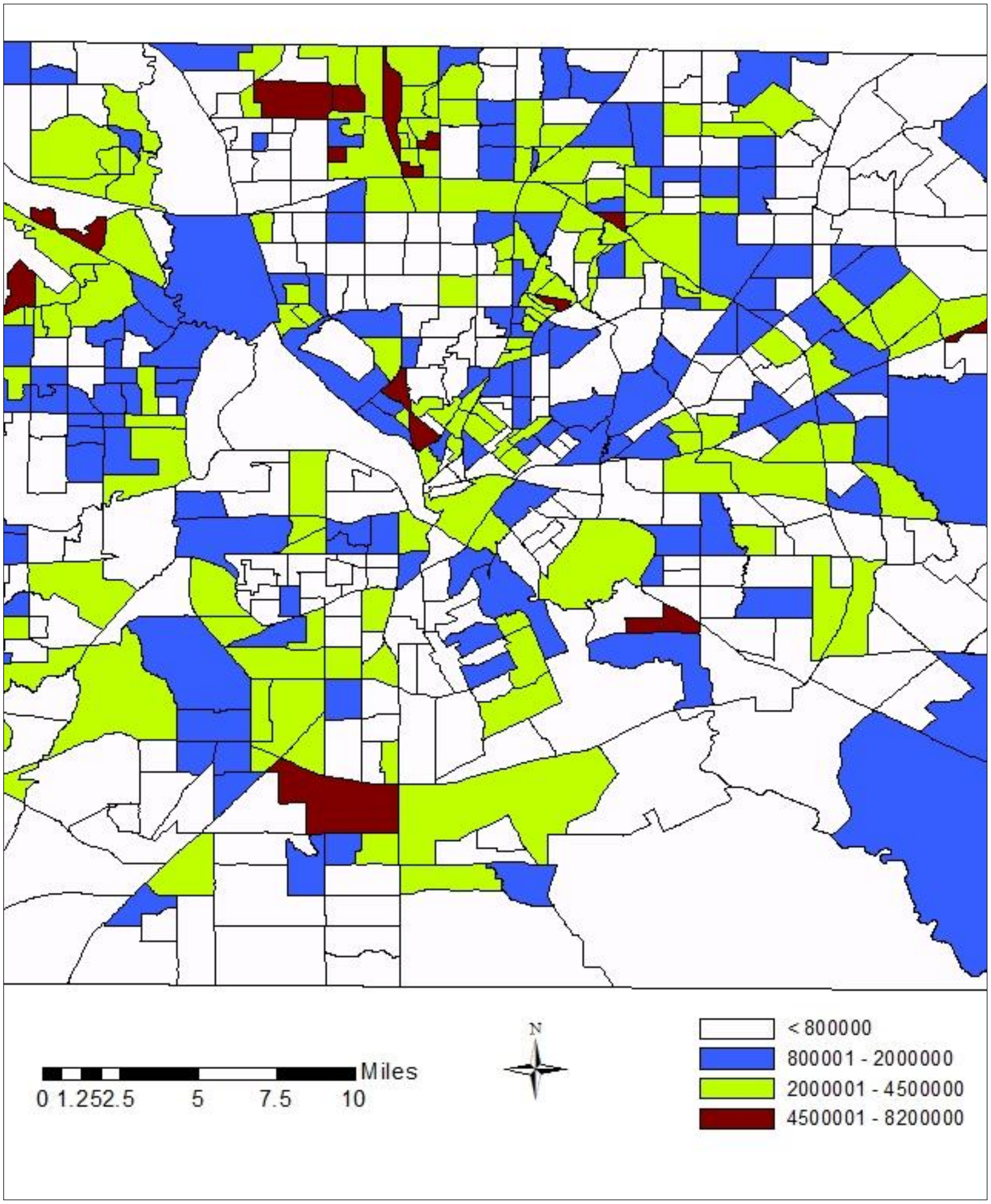


Figure 14 Multi-family residences

3.3 Travel characteristics of workers

Dallas County ranks high among the regions experiencing "wasteful commute". Table 4 gives a list of cities in the US ranking high in terms of wasteful commute, and the Dallas-fort worth area is identified as a region with Travel time index of 1.23 as of 2010.

Table 4 Congestion trends in terms of wasted time (Travel Time Index, 1982-2010)

Urban Area	**Travel time index**				
	2010	**2009**	**2006**	**2000**	**1982**
Washington DC	1.33	1.30	1.35	1.31	1.11
Seattle, WA	1.27	1.24	1.33	1.31	1.08
Dallas, Fort Worth, TX	1.23	1.22	1.27	1.20	1.05
New York-Newark, NY-NJ-CT	1.28	1.27	1.37	1.28	1.10
Los Angeles-Long Beach-Santa Ana, CA	1.38	1.38	1.42	1.39	1.21
Chicago, IN	1.24	1.25	1.29	1.21	1.08
San Francisco- Oakland, CA	1.28	1.27	1.40	1.34	1.13
Atlanta, GA	1.23	1.22	1.28	1.25	1.08
San Diego, CA	1.29	1.18	1.25	1.20	1.04
Miami, FL	1.23	1.23	1.31	1.27	1.09
Travel Time Index= Ratio of travel time in the peak period to the travel time in free flow conditions. A value of 1.30 indicates a 20 minutes free flow trip, which takes 26 minutes in the peak period.					

(*Source: Lomax, Schrank et al. 2011*)

Moreover, the MTT for workers 16+ in age is around 25.7, breaking it down, in 15.5% census tracts it is less than 20 minutes whereas 32.5% have it between 20 to 25 minutes, 31.4% in a range of 25 to 30 minutes, and the rest have a travel time of more than 30 minutes. Therefore, greater part of the workers travels more than 25 minutes one-way to work in the area. Figures 15-18 give a spatial picture of travel characteristics for Dallas County.

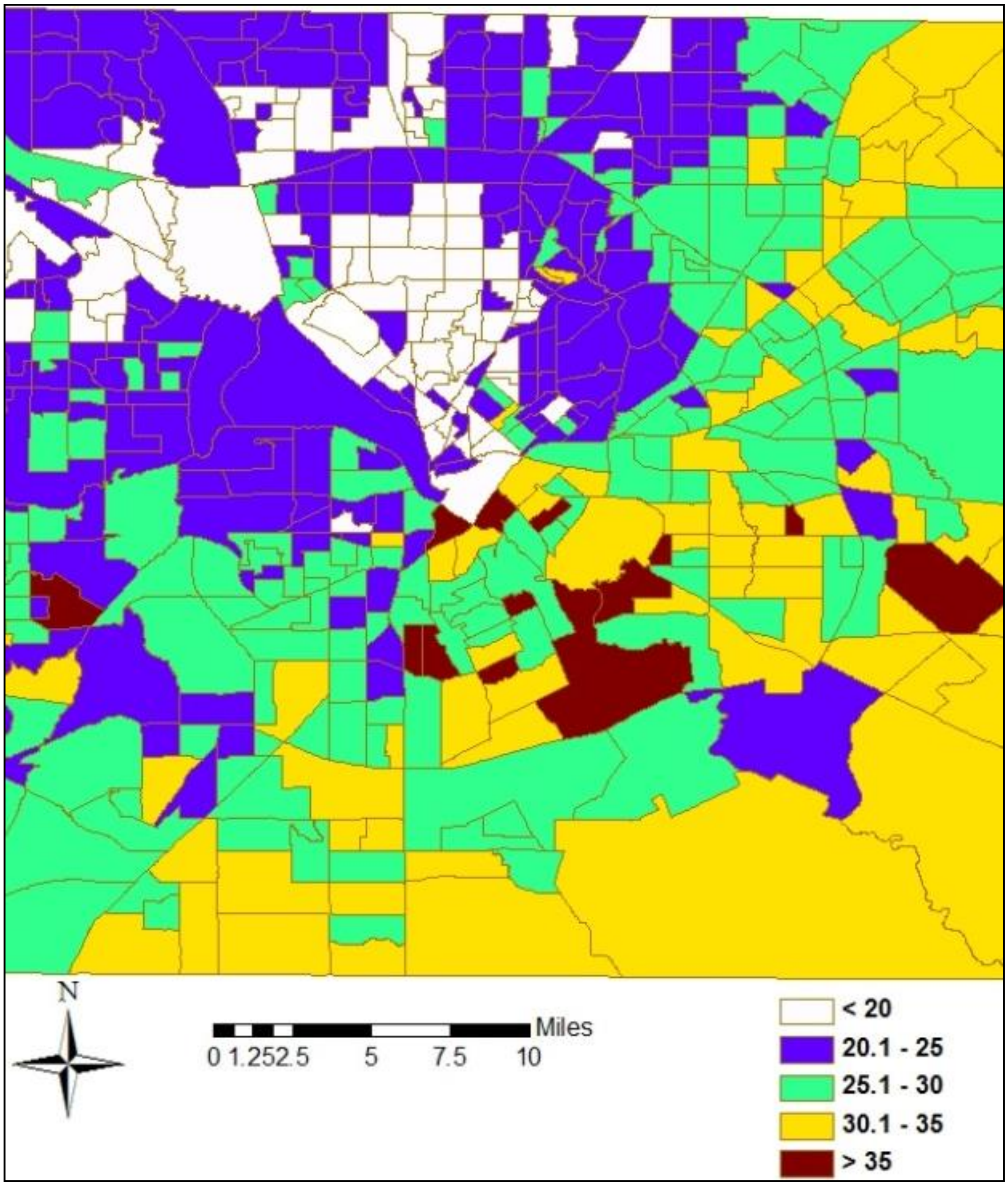


Figure 15 MMT to work

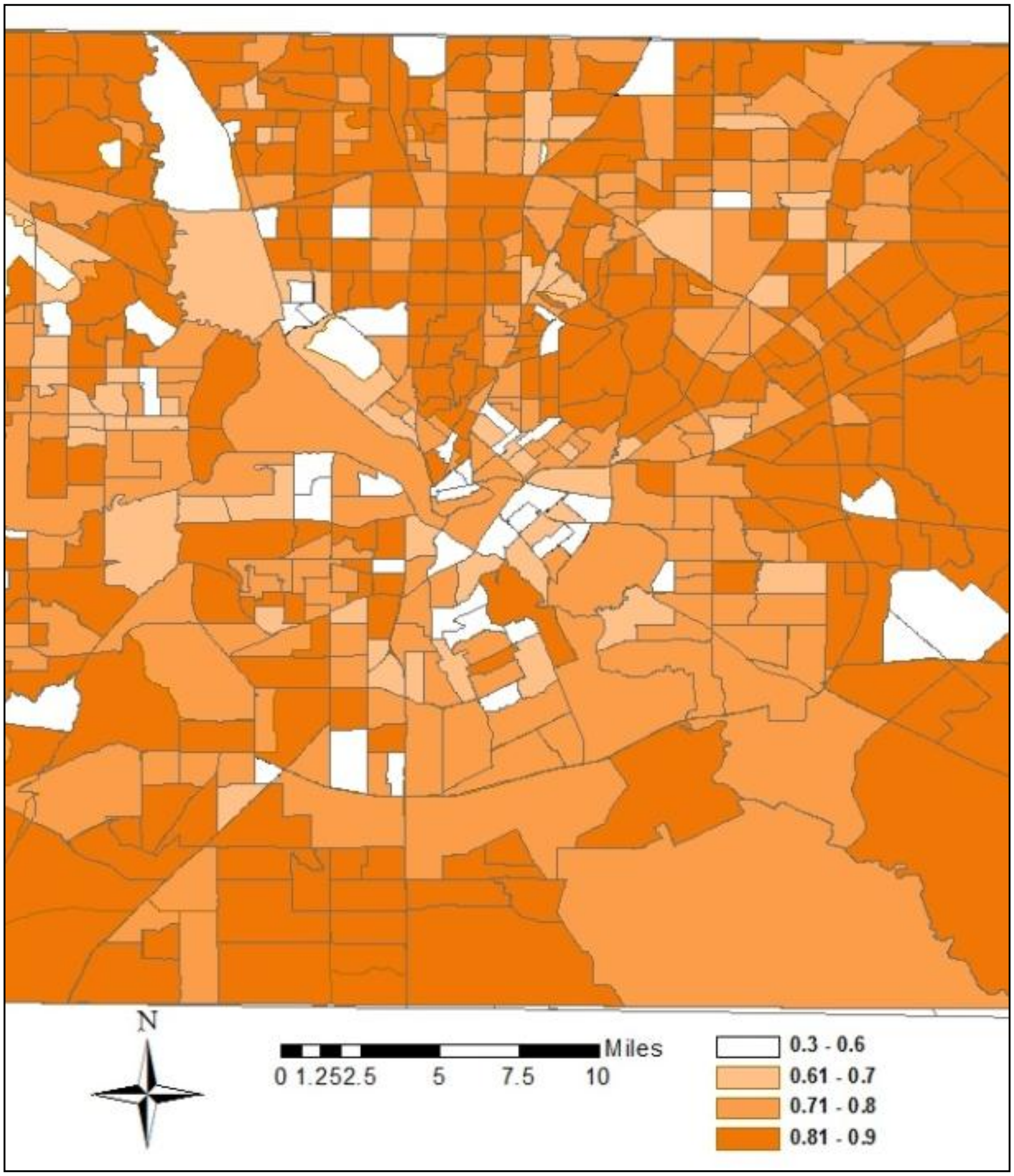


Figure 16 Median personal vehicles

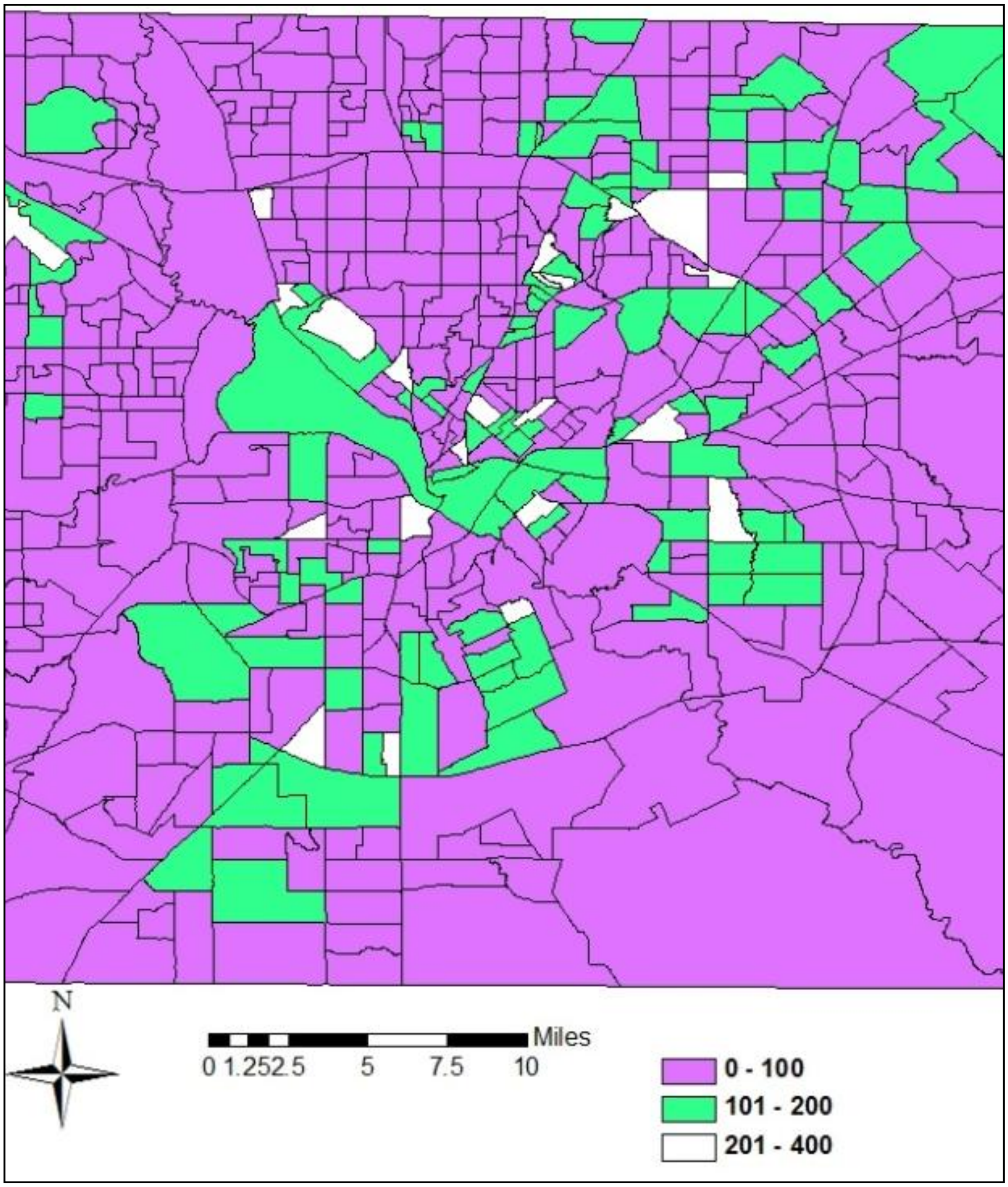


Figure 17 Workers taking public transit to work place

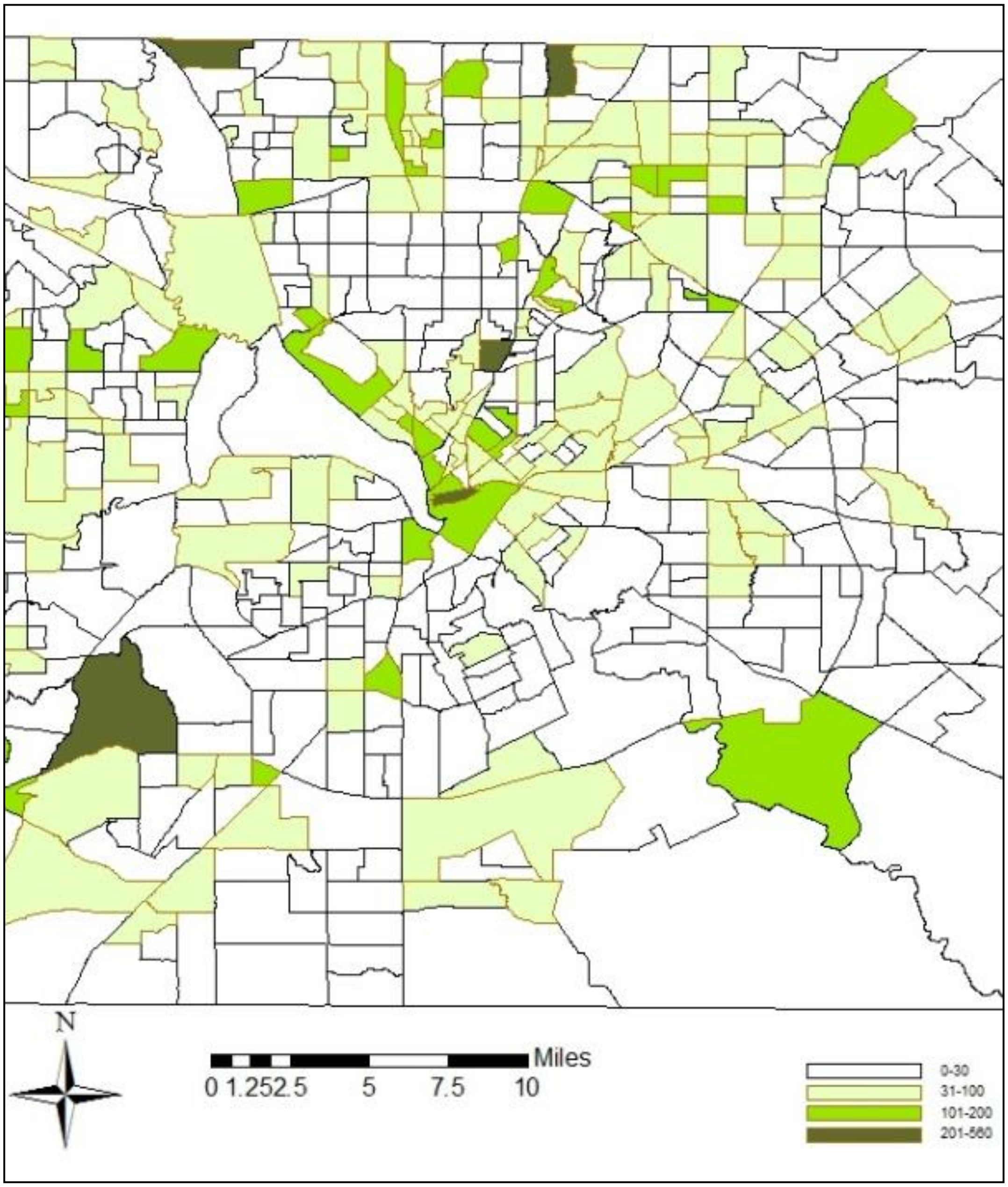


Figure 18 Workers walking to the work place

3.4 Data sources for the research

The following data sources will be used for the analysis:

3.4.1 US census data

This study relies primarily on US Census data for workers demographic, socio-economic and travel characteristics.

3.4.2 NCTCOG

GIS shapefiles including county boundary, census tracts, land use and other required GIS data is obtained from The North Central Texas Council of Governments[1] (NCTCOG) clearing house website. It maintains many useful shape files and other important related meta data. Its GIS Data Clearinghouse offers free of charge downloadable GIS files such as highways, roads, water bodies, railroads, census tracts, census blocks and political boundaries, landmarks, historical sites and a lot of other such information for the city/county of Dallas.

3.4.3 LED, LHED and QWI data

LHED[2], LED[3], QWI[4] data offers unprecedented information about the workers, their travel and socio economic characteristics, local economies etc for the US. The 'On

[1] The North Central Texas Council of Governments (NCTCOG) is a voluntary association of, by and for local governments, and was established to assist local governments in planning for common needs, cooperating for mutual benefit, and coordinating for sound regional development.

[2] Longitudinal Employer-Household Dynamics (LEHD) is a ground-breaking program in the U.S. Census Bureau which uses statistical estimation methods to join federal and state administrative data of employers and employees using core Census Bureau censuses and surveys.

[3] Local Employment Dynamics (LED) is a voluntary collaboration, between state labor market information agencies and the U.S. Census Bureau to gather innovative information about labor market, workers job places and their residences without any questionnaire and respondent burden.

the Map' tool in LHED data investigates the place of work and residential distributions by user specified geographies at different levels (census tracts, census block groups, TAZ etc)(Source: http://lehd.did.census.gov/led/). It generates maps and its related description which show a 'labor shed' (where workers arrive from that are employed in the chosen area) and a 'commute shed' (where workers are employed that reside in the selected area). In addition to worker inflows and outflows, the application also provides adjoining details on job and housing area disparities, workers movement and commuting patterns by specific details of workforce e.g. ages, race, sex, education attainment, earnings or industry types. Data is accessible ranging for years between 2002-2010 and the data sources are elaborated in Figure 19. This data is used to determine where and how many people work and where those same individuals live in and around Dallas County. (Source: http://lehd.did.census.gov/led/)

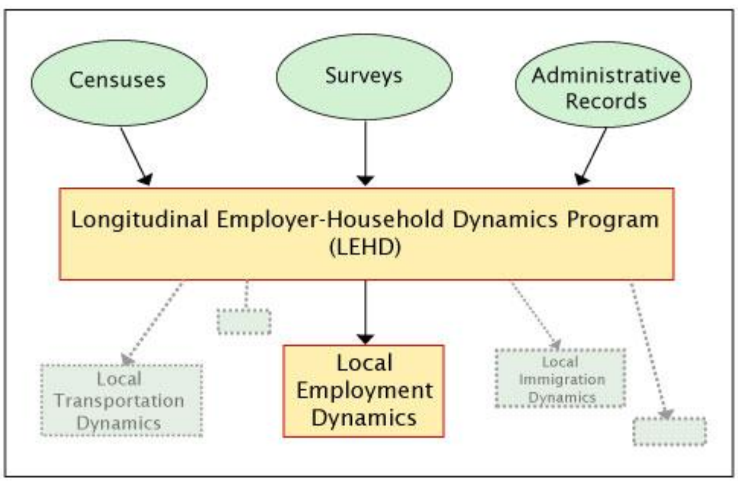


Figure 19 LHED Flow chart

(Source: http://lehd.did.census.gov/led/)

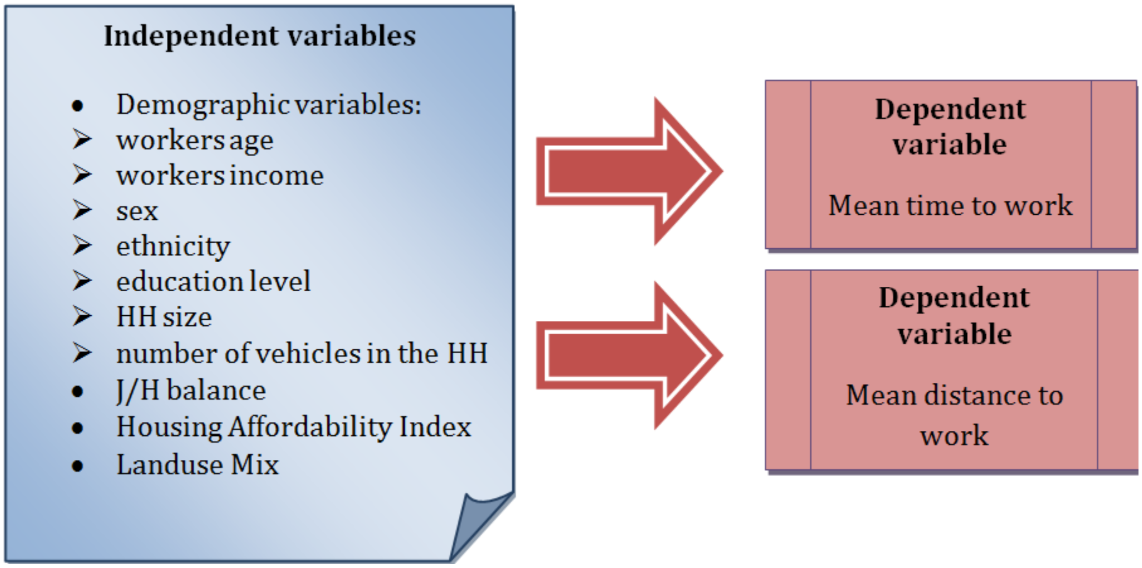
4 The Quarterly Workforce Indicators (QWI) are a series of eight economic indicators namely employment, job creation, wages, and worker turnover etc that can be analyzed by specific industry, gender, and age at different levels of geography e.g. state, county, metro, census blocks and workforce investment.
(Source: http://lehd.did.census.gov/led/)

3.4.4 Transit system travel pattern analysis study by NuStats

The study seeks to use the data collected in the 2007 Transit System Travel Pattern analysis study conducted by NuStats. The firm conducted an origin/destination survey of the riders of Dallas Area Rapid Transit (DART) and bus services. The self-administered surveys were conducted on fixed-route bus riders as well as Light Rail and Trinity Express railroad riders of DART. Data collection was conducted from April 4 through May 24, 2007. A total number of 7,813 completed and usable surveys were retrieved. The results provide detailed information on the demographic characteristics, travel behavior and travel pattern characteristics of DART riders. The study collected data from riders of both the bus and rail systems, including the Trinity Railway Express commuter rail line that connects Dallas and Fort Worth.

The research aims to take the NuStats data from the DART report and putting it into GIS environment. Next step is to geocode all the work trips origin-destinations onto the map. The results are as shown in the map. The excel table carrying all the trip makers characteristics like age, sex, income, household size, number of vehicles in the house hold etc is attached to these events' shapefile. It also carries information about the trip characteristics like distance covered, transfers made, bus-only riders, rail-only rider, travel time etc.

Conceptual framework of the research



3.5 Research methodology

The modus operandi of this research consists of the following steps:

- Identification and background of the problem
- Review of the relevant literature
- Explanation of the case study area and data sources
- Data Analysis :

The initial task is to generate the following maps in GIS:

- ✓ Map of Dallas county showing Labor shed and commute shed for Dallas county workers
- ✓ Map of Dallas County showing Job-housing balanced and imbalanced areas (job-rich housing-poor, housing-rich job poor)etc
- ✓ Map of Dallas County showing the landuse mix with regards to the entropy score/index.

- Next, the research methodology comprises of performing ANOVA, curve estimation and regression on all of the above compiled data in GIS, in order assess the of job-housing balanced and imbalanced areas in Dallas county. Moreover the task is to link the job housing locations with the landuse mix within the area and determine their relation with commute time to job centers.

- MLR model is executed with "Time to work place" as the dependent variable. The independent variables can be subdivided into four categories socio-economic variables (age, sex, income etc), travel characteristics, J/H balance and LUM. Since there are many independent variables, the study will first examine the relationship among them. This is to check whether they do/ do not have much variance or if the correlations are strong. Consequently, as a primary step, the data was analyzed with Pearson’s product moment correlation coefficients for testing the association between the independent variables. After this correlation analysis check among the dependent variable and the independent variables to assess the preliminarily relationships, regression analysis is conducted to find out the specific impacts of each. Subsequently decision is taken to check the significance (in other words, if the model has accounted for a significant proportion of the variance), to achieve this purpose F-statistics and R squared (multiple coefficient of determination) are examined. Finally, the relative importance of each variable will be assessed. Model accuracy and validity is checked by performing model sensitivity tests (PP plot, histogram check for normality, VIF and tolerance, Durbin Watson Test etc)

- GIS Analysis is conducted using Geo Statistical and Spatial Analyst tools with US Census Data representing all trips and DART data characterizing transit trips exclusively. Target Area Analysis and Hot Spot Analysis present a spatial picture of areas J/H parity and LUM. It also gives the stress maps to identify action areas for policy makers.

4. ANALYSIS OF LHED, LED AND QWI DATA

In order to better understand the work commute in Dallas County, it’s significant to inquire the distance, direction and pattern of the workers movement. The first step of the analysis is to work with LHED, LED and QWI data and generate the job-housing topology for Dallas County. For this purpose six types of analysis have been made using "On the Map" tool:

- Area profile analysis
- Area comparison analysis
- Distance/direction analysis
- Destination analysis
- Inflow/outflow analysis
- Paired area analysis

4.1 Area profile analysis

This analysis gives us the count, characteristics and spatial locations of jobs and workers residences, within census block level data for Dallas County. Figure 18 shows "Work Area Profile Analysis" (Where are the jobs) on the left and "Home Area Profile Analysis"(where do workers live) on the right. The generated maps show employment locations in Dallas County in the left map and workers residences on the right map. The data is represented by blue thermal density overlay showing jobs per square mile. The work locations are also aggregated in points for each census block. Census block where employment is absent will not show a blue dot. The residential locations are also aggregated in points for each census block. Census block where there is no workers residence will not show a blue dot. The north and north-eastern Dallas area are found to be really attractive places to reside for most of the workers and for the youngsters the downtown and uptown Dallas area is considered magnetic, the families with children mostly focus towards the North-eastern side including cities like Garland, Richardson, Rowlett and Mesquite. Employment is mostly concentrated in the north and north western parts of the county including Irving, Addison, Farmers branch, University Park/ Highland Park etc. However, Desoto in the south is also a job attraction. Table 5 and 6 give the detailed statistics for Work Area Analysis and Home Area Analysis respectively. The same analysis is depicted in graphical form in Figure 20.

Table 5 Job counts top 6 cities Dallas County 2010 -work area profile

Dallas city, (Partial)	722,261
Irving	183,707
Richardson city, (Partial)	67,073
Farmers Branch city	59,380
Garland city (Partial)	56,780
Carrollton city, (Partial)	47,983

Table 6 Job counts top 6 cities Dallas County 2010 -home area profile

Dallas city, (Partial)	403,292
Garland city, (Partial)	92,082
Irving	88,786
Mesquite city, (Partial)	56,368
Grand Prairie city, (Partial)	46,814
Richardson city, (Partial)	32,046

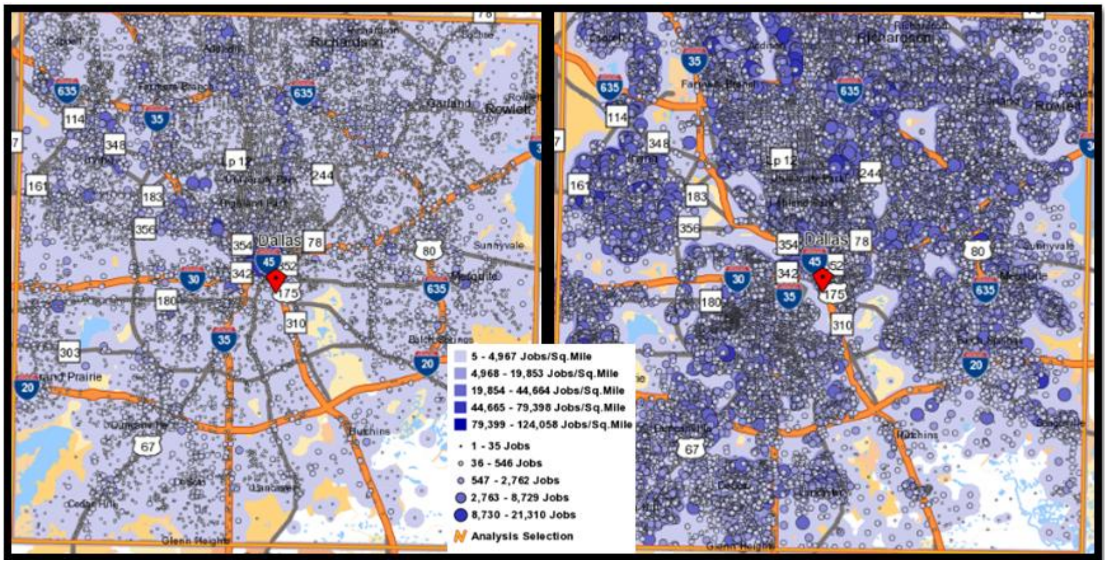


Figure 20 Work area and home area profile analysis

4.2 Area comparison analysis

This analysis gives workers work area comparisons and workers home area comparisons. The resultant map in Figure 21 shows employment locations in the form of blue thematic overlays, aggregated to the top 100 census blocks contained (wholly or partially) within Dallas County. Similarly, the resultant map in Figure 22 shows workers residence locations in the form of blue thematic overlays, aggregated to the top 100 census blocks contained (wholly or partially) within Dallas County. The contrast between where most of the workers live and where they work are seen in the two maps, depicting a clear picture of **job-housing imbalance** within the study area.

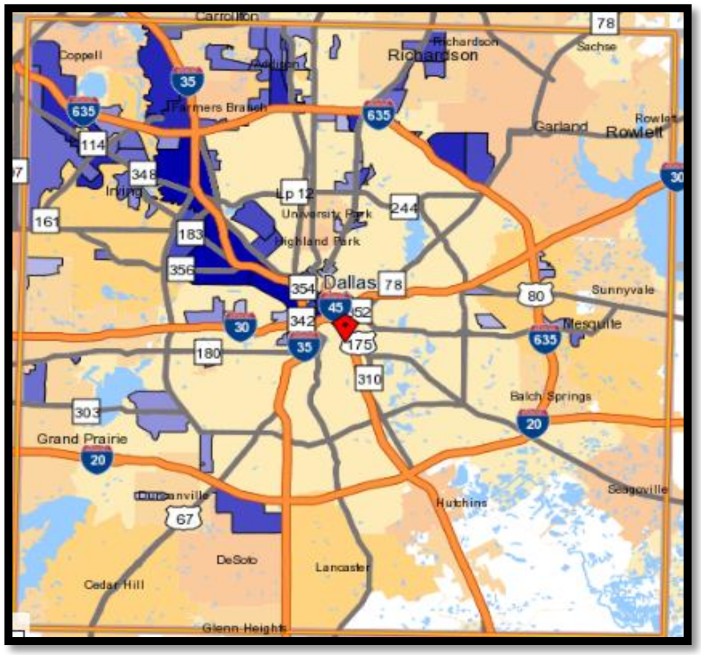


Figure 21 Top 100 census blocks with highest number of jobs

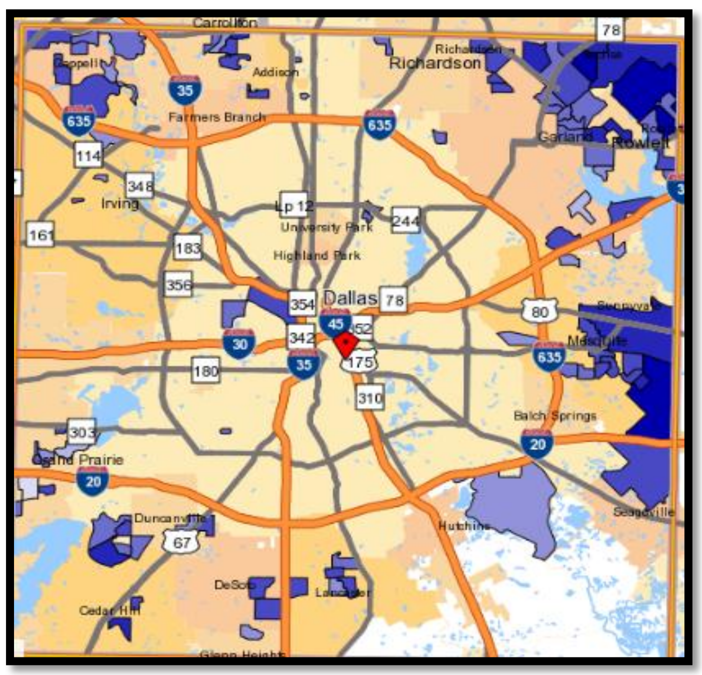


Figure 22 Top 100 census blocks with highest number of workers residences

4.3 Distance/direction analysis

This gives spatial distribution of worker commutes. This performs Distance/Direction Analysis for "Work to Home" (Table 7) as well as "Home to Work" (Table 8) in other words it generates the distance and direction totals between the dwellings and employment settings for workers employed or living in Dallas County. The tables below portray a clear picture of commute to work trends, more than 55% of workers travel greater than 10 miles to reach their workplace.

Table 7 Jobs by distance (2010) -work census block to home census block

Work to Home	**Count**	**Share**
Total Primary Jobs	1,340,236	100.0%
Less than 10 miles	437,558	32.6%
10 to 24 miles	550,861	41.1%
25 to 50 miles	153,301	11.4%
> than 50 miles	198,516	14.8%

Table 8 Jobs by distance (2010) -home census block to work census block

Home to Work	**Count**	**Share**
Total Primary Jobs	914,174	100.0%
Less than 10 miles	403,623	44.2%
10 to 24 miles	346,625	37.9%
25 to 50 miles	62,746	6.9%
> than 50 miles	101,180	11.1%

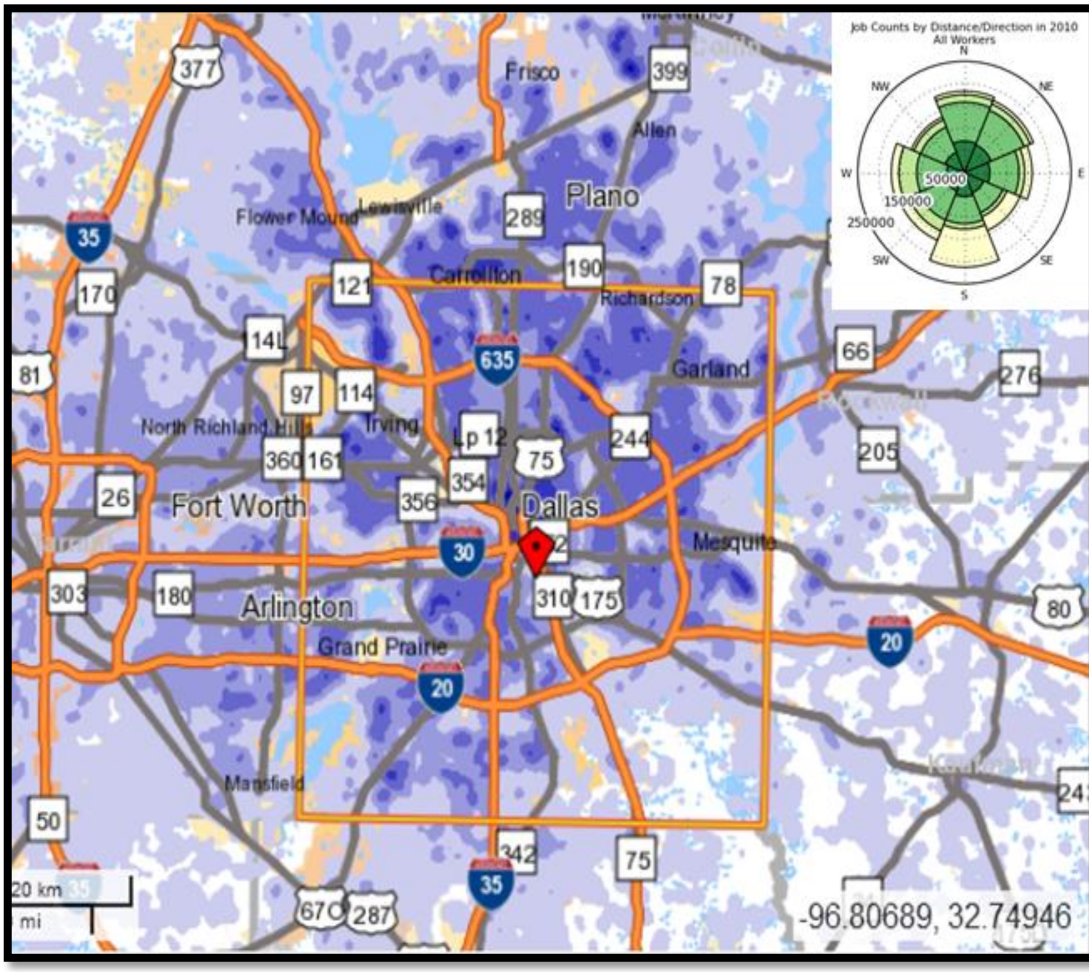
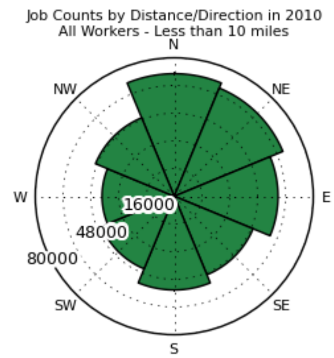


Figure 23 Work to home analysis

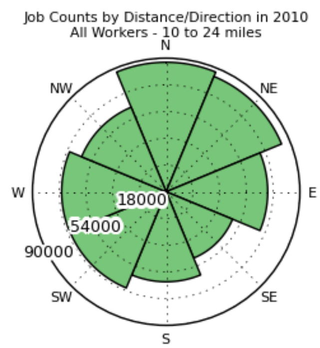
Figure 23 shows "Work to home analysis" (analyzing movement of workers from work places to homes).This calculates the distance and direction data between every home to work census tract pair included in the analysis. The radar chart on the top left of the map gives green and yellow colored boxes, with darkest green color representing the shortest trips (less than 10 miles) and yellow representing the direction of longest trips (greater than 50 miles). Further directional breakdown with respect to distance travelled for work to home analysis is given in Table 9.

Table 9 Directional breakdown of work to home analysis

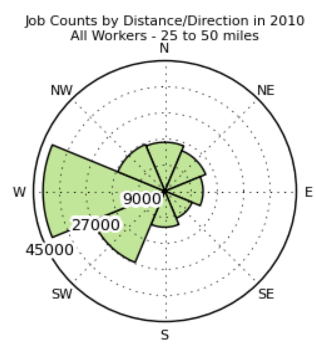
Less than 10 miles	Count	Share
Total Primary Jobs	437,558	100.0%
North	70,818	16.2%
North East	67,676	15.5%
East	59,721	13.6%
South East	49,121	11.2%
South	54,153	12.4%
South West	45,393	10.4%
West	41,581	9.5%
North West	49,095	11.2%



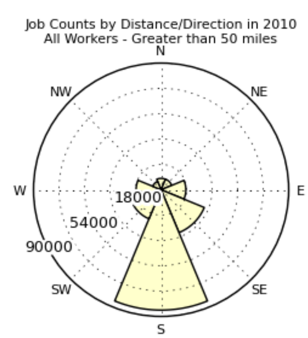
10 to 24 miles	Count	Share
Total Primary Jobs	550,861	100.0%
North	87,241	15.8%
North East	84,080	15.3%
East	68,355	12.4%
South East	48,382	8.8%
South	60,659	11.0%
South West	70,165	12.7%
West	70,348	12.8%
North West	61,631	11.2%



25 to 50 miles	Count	Share
Total Primary Jobs	153,301	100.0%
North	16,872	11.0%
North East	15,100	9.8%
East	13,056	8.5%
South East	10,077	6.6%
South	12,423	8.1%
South West	26,629	17.4%
West	41,719	27.2%
North West	17,425	11.4%



> than 50 miles	Count	Share
Tot. Primary Jobs	198,516	100.%
North	8,069	4.1%
North East	8,146	4.1%
East	17,453	8.8%
South East	32,949	16.6%
South	85,515	43.1%
South West	22,318	11.2%
West	17,625	8.9%
North West	6,441	3.2%



For work census block to home census block, the longest commutes are towards the western and southern side of the county and the shortest ones are found along every direction but mostly concentrated along the north and north eastern quarter of the county. Figure 24 shows "Home to work analysis" (analyzing movement of workers from their home places to wherever their workplace maybe). Further directional breakdown with respect to distance travelled for home to work analysis is given in Table 10.

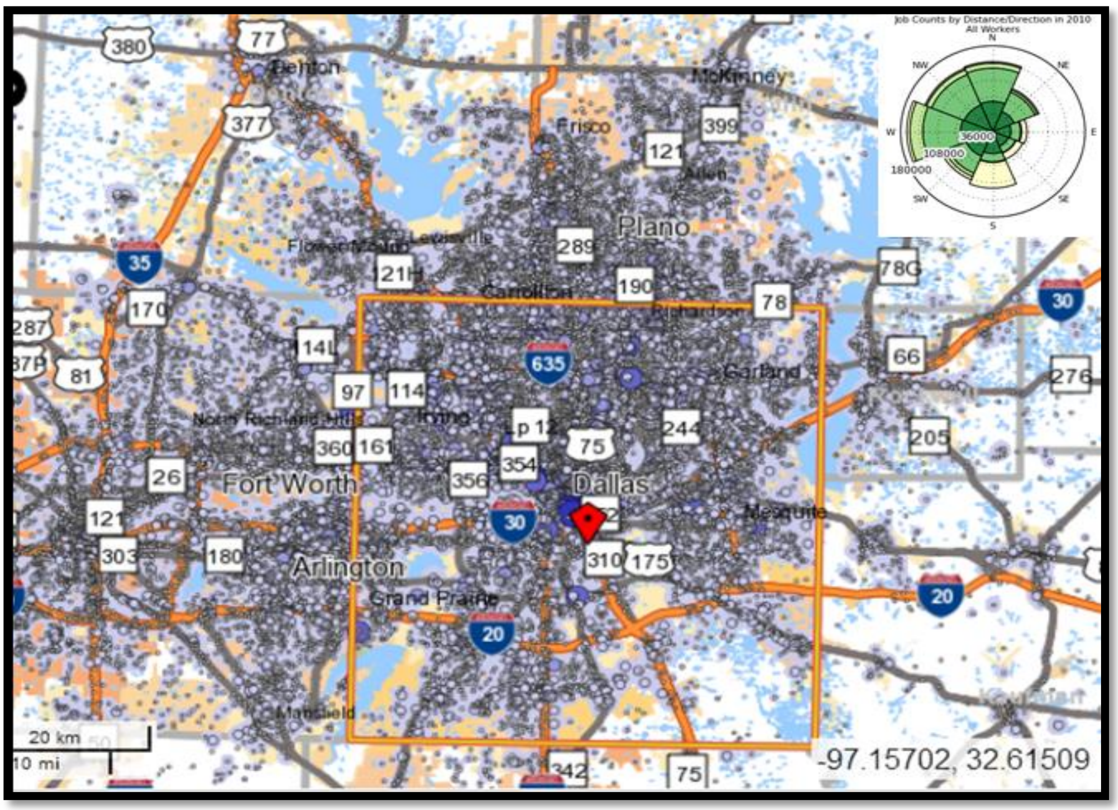
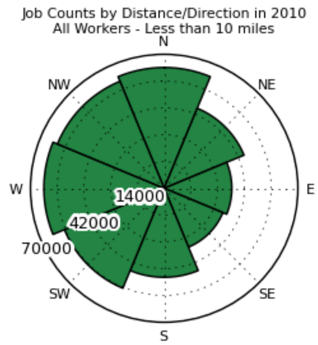
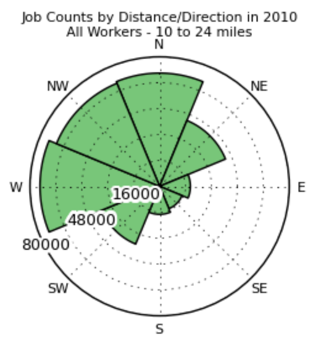


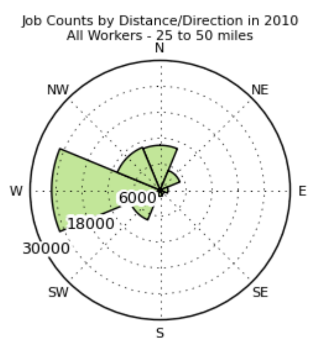
Figure 24 Home to work analysis

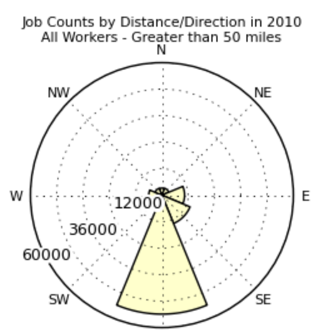
Table 10 Directional breakdown of home to work analysis

Less than 10 miles	Count	Share
Total Primary Jobs	**403,623**	**100.0%**
North	**63,116**	**15.6%**
North East	**45,249**	**11.2%**
East	**35,419**	**8.8%**
South East	**33,270**	**8.2%**
South	**46,523**	**11.5%**
South West	**56,535**	**14.0%**
West	**62,988**	**15.6%**
North West	**60,523**	**15.0%**
10 to 24 miles	**Count**	**Share**
Total Primary Jobs	**346,625**	**100.0%**
North	**69,946**	**20.2%**
North East	**44,015**	**12.7%**
East	**18,991**	**5.5%**
South East	**14,967**	**4.3%**
South	**17,334**	**5.0%**
South West	**38,631**	**11.1%**
West	**73,843**	**21.3%**
North West	**68,898**	**19.9%**
25 to 50 miles	**Count**	**Share**
Total Primary Jobs	**62,746**	**100.0%**
North	**10,360**	**16.5%**
North East	**4,924**	**7.8%**
East	**1,810**	**2.9%**
South East	**1,053**	**1.7%**
South	**1,423**	**2.3%**
South West	**7,449**	**11.9%**
West	**25,041**	**39.9%**
North West	**10,686**	**17.0%**
> than 50 miles	**Count**	**Share**
Total Primary Jobs	**101,180**	**100.0%**
North	**3,189**	**3.2%**
North East	**3,362**	**3.3%**
East	**10,344**	**10.2%**
South East	**13,882**	**13.7%**
South	**53,895**	**53.3%**
South West	**7,182**	**7.1%**
West	**5,985**	**5.9%**
North West	**3,341**	**3.3%**









For home census block to work census block, the longest commutes are the same as from work to home i.e. towards the western and southern side of the county but the shortest ones are mostly concentrated along the north and north western quarter of the county. Thus we can conclude that the work trips are longest for the incoming and outgoing workers commuting in the count and south-western quart of the county, and trips are shorter in the north eastern side for the non-resident workers and north western quart for the resident workers of the county.

4.4 Destination analysis

This performs work destination analysis and home destination analysis of workers employed or living in our selection area i.e. Dallas county.

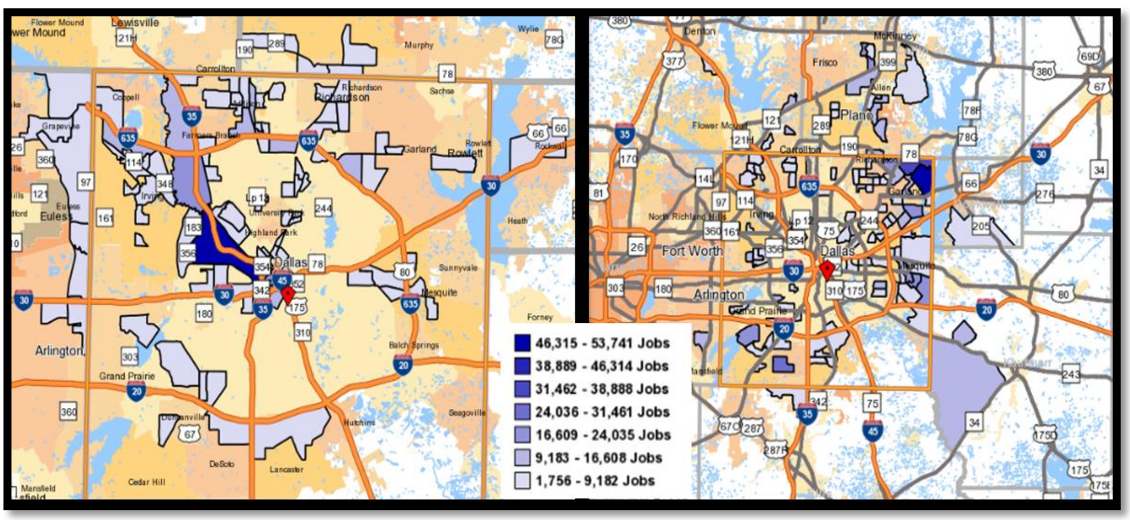


Figure 25 Work destination analysis & home destination analysis

The resultant map in Figure 25 above shows "Work Destination Analysis"(left), illustrating movement of workers from home places to workplaces, so it shows top 100 census blocks where workers commute from Dallas County; these are represented by a blue thematic overlay. "Home Destination Analysis"(right) shows movement of workers from work places to their home place, i.e. where workers live who are employed in Dallas. The left map indicates north western side of the county as Job rich, additionally many workers residing in the Dallas County, go to the bordering cities on the west, far north Dallas, outside the jurisdiction of county to work. Similarly the right map indicates that many workers of the Dallas County reside in the Plano-McKinney area in the north, heath area on the eastern side and Seagoville-Crandall area of Kaufmann county on the south-eastern side. Below are the same maps that show census tract with spokes indicating the movement of workers to work destinations in the left map and the movement of workers to home destinations in the right (Figure 26).

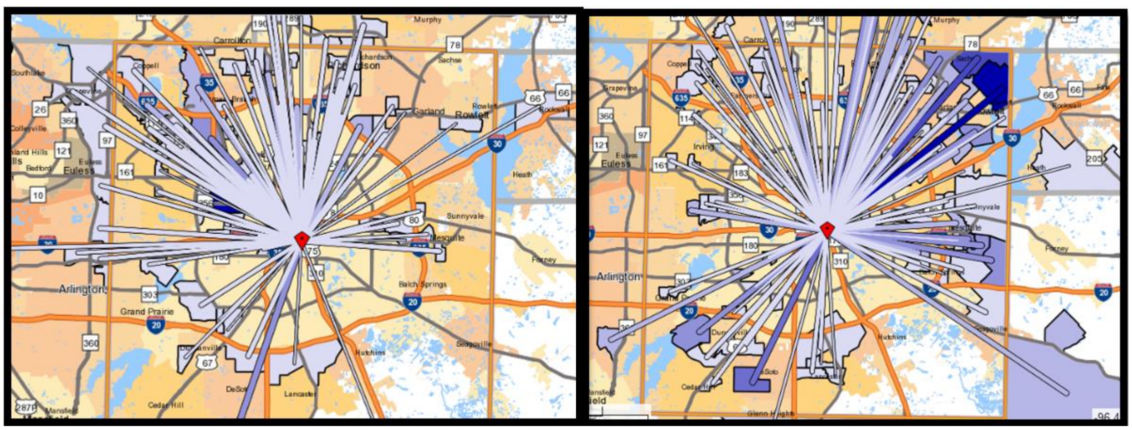


Figure 26 Work destination analysis & home destination analysis with spokes

4.5 Inflow/ outflow analysis

This highlights movement of workers commuting in and out of Dallas County. Thus the county is being analyzed as both a labor force source and destination. Table 11 summarizes the statistics of workers coming in and going out of the county for work.

Table 11 Inflow/Outflow job counts (primary jobs) 2010

Workers	Count	Share
Employed in Dallas County	1,340,236	100.0%
Employed in Dallas County but Living Outside	718,934	53.6%

Table 11 (Continued)

Workers	Count	Share
Employed and living in Dallas County	621,302	46.4%
Living in Dallas County	914,174	100.0%
Living in Dallas County but Employed Outside	292,872	32.0%
Living and Employed in the Dallas County	621,302	68.0%

Figure 27 gives the resultant Map from Inflow/ Outflow Analysis. Worker flow dynamics are represented by green arrows, however the direction of arrows do not symbolize the direction of the flow. Workers employed in Dallas County but residing outside are presented by the arrow entering Dallas (718,934) and workers employed outside the county but living in Dallas is symbolized by arrow exiting the County (292,872). Workers who live as well as work in the County are given by the circular arrow (621,302). The Venn diagram on the top right of the map indicates the inter and Intra county work trips, the intersected portion presents the amount of workers living and employed in the Dallas County, the rest of the workers commute inter-county to reach their work place. This shows that Dallas County acts primarily as a labor force hub and secondary as a labor force provider.

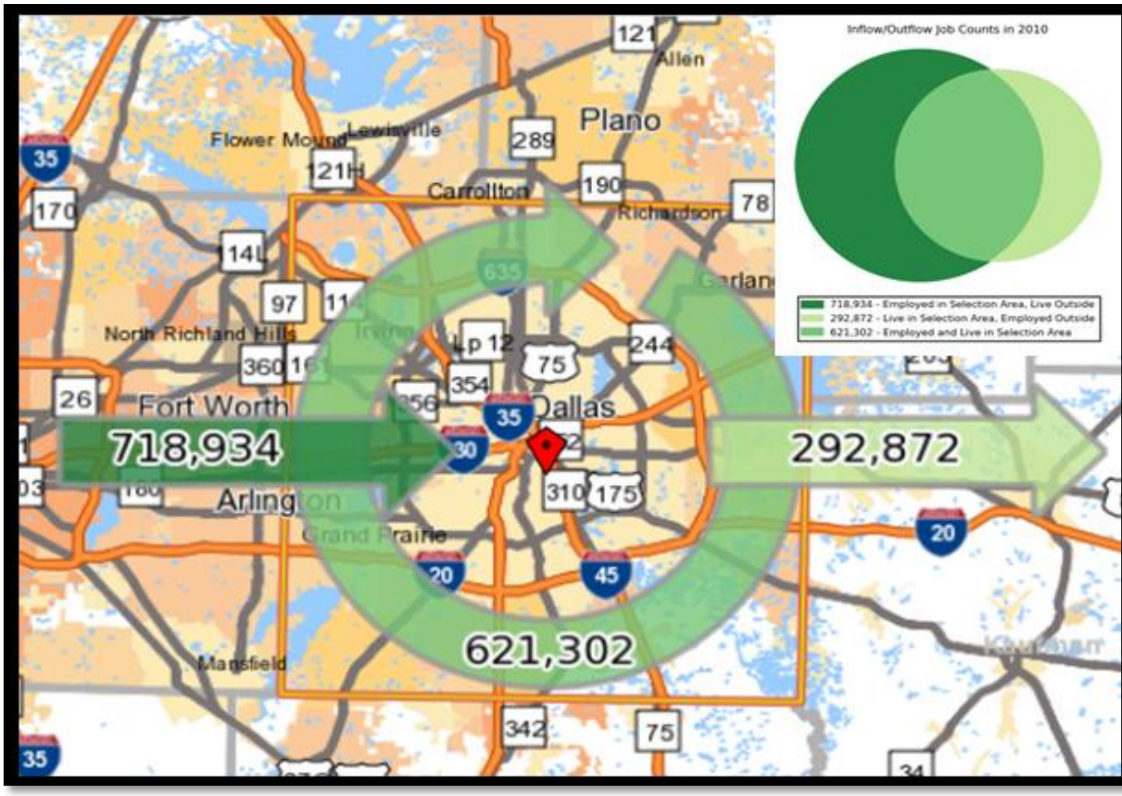


Figure 27 Inflow/Outflow Analysis

4.6 Paired area analysis

The inflow/outflow analysis in the previous section gave us the summarized results of workers coming in and going out of the Dallas County. Furthermore, the paired area analysis will help investigate Inter-county work commute trips from Dallas County to the adjacent counties. Figure 28 shows the working of Paired area analysis and the Table 12 summarizes the work trips made in 2010.

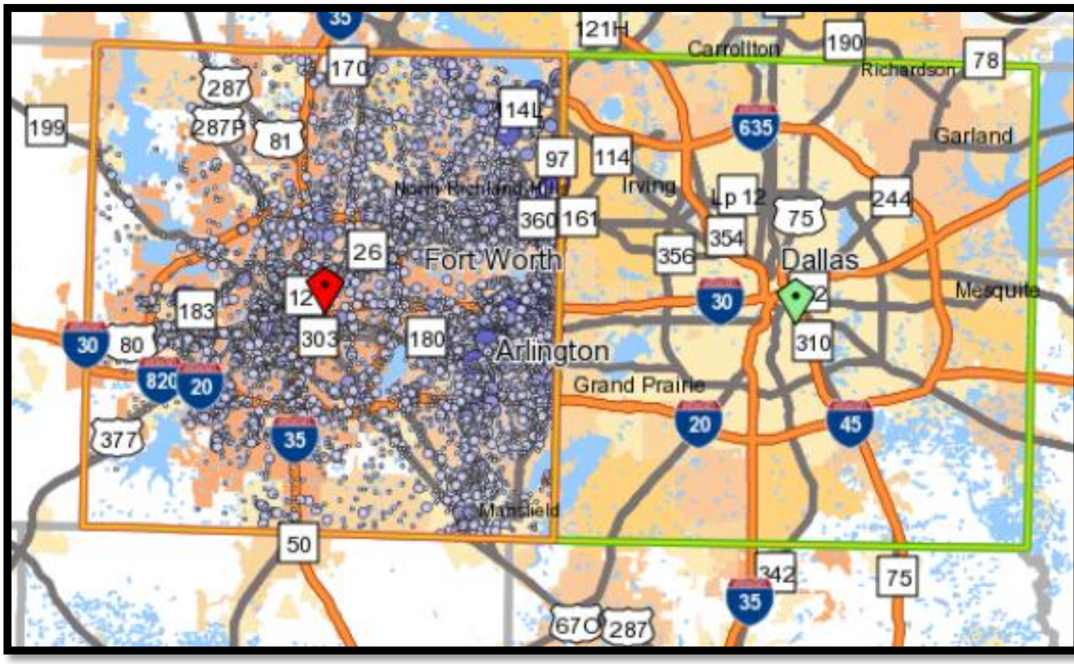


Figure 28 Paired area analysis

Table 12 Workers flow to and from the counties surrounding Dallas County

Adjacent Counties surrounding Dallas County	Non-Resident Workers	Resident Workers
Denton County	156,606	63,162
Collin County	111,081	24,267
Kaufman County	21,607	3,345
Ellis County	25,398	4,399
Tarrant County	170,913	88,342
Rockwall County	16,815	5,218
Total	502,420	188,733

The analysis clearly indicates a lot of inter-county activity taking place. As was expected, the inflow of workers is much greater than the outflow of workers owing to a greater number of employment opportunities in Dallas, as compared to the surrounding counties. However the greatest inflow is from the Tarrant County, followed by Denton and Collin County respectively. The same county order follows when we check the outflow but definitely with fewer workers leaving Dallas and going to other counties for work. However, when the results of Inflow/out flow analysis were compared to the paired area analysis, we come to know that 2,16,514 trips have been made from places beyond the surrounding counties to the Dallas county and 1,04,139 trips have been made from the Dallas county to places beyond the adjacent counties. This reveals the extent of extra mileage travelled by people to reach their employment places.

5. ANALYSIS OF JOBS/HOUSING RATIO

As a first step a Jobs/Housing Ratio Map was prepared in GIS. Shapefiles for Dallas and the 6 surrounding counties were downloaded from the Census Bureau website. Excel tables having information on the number of households and workers living in Dallas county were also obtained from American Factfinder 2 (Bureau 2010). These tables were converted to data base files, so as to join them to the GIS shapefiles. Figure 29 shows final output of the acquired information.

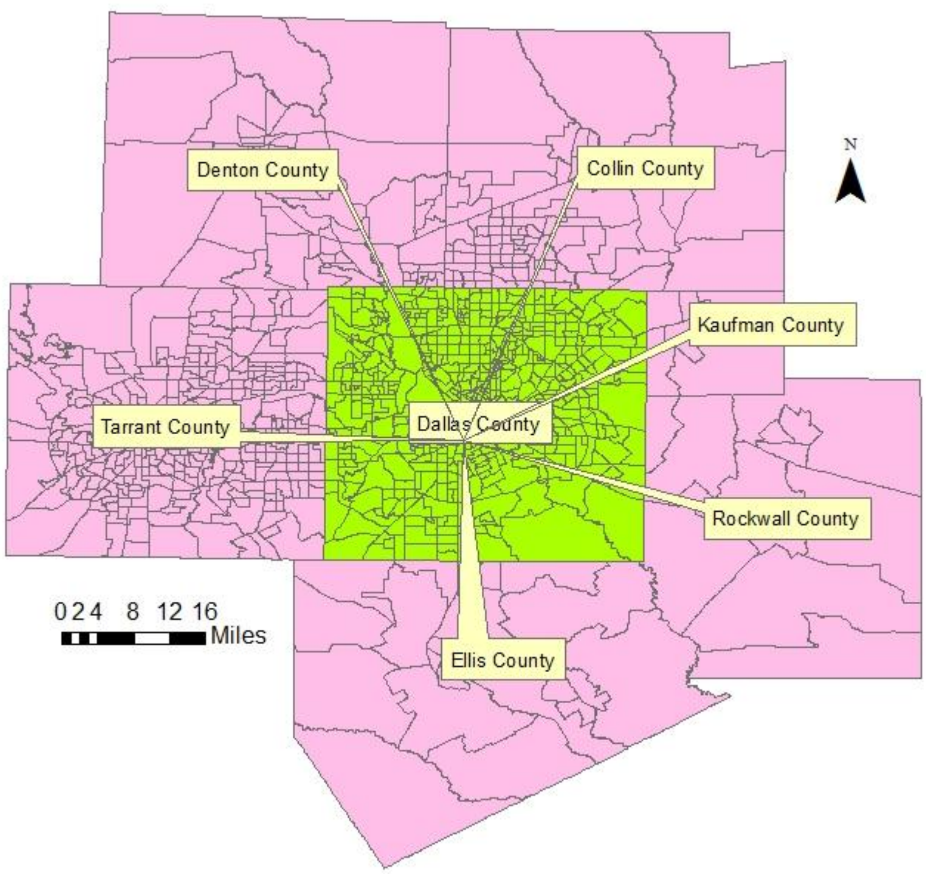


Figure 29 GIS map for Dallas and surrounding counties

The next step in the procedure includes generating the centroid of each census tract in GIS and then the dynamic buffering of every centroid by a 7 mile circular buffer. The standard of 7-mile is adapted from the previous practices and calculations of Jobs/housing ratio (Livingston 1989; Peng 1997; Sultana 2002). JHR for each census tract was found by dividing the number of workers by the number of households in each buffer around the centroid of each census tract. Maps and census data for the surrounding boundary counties was acquired in order to provide the complete information for the boundary census tracts. These counties include Tarrant, Rockwall, Kaufman, Ellis, Denton and Collin. Figure 30 portrays the information on boundary counties and buffers to the centroid of each census tract.

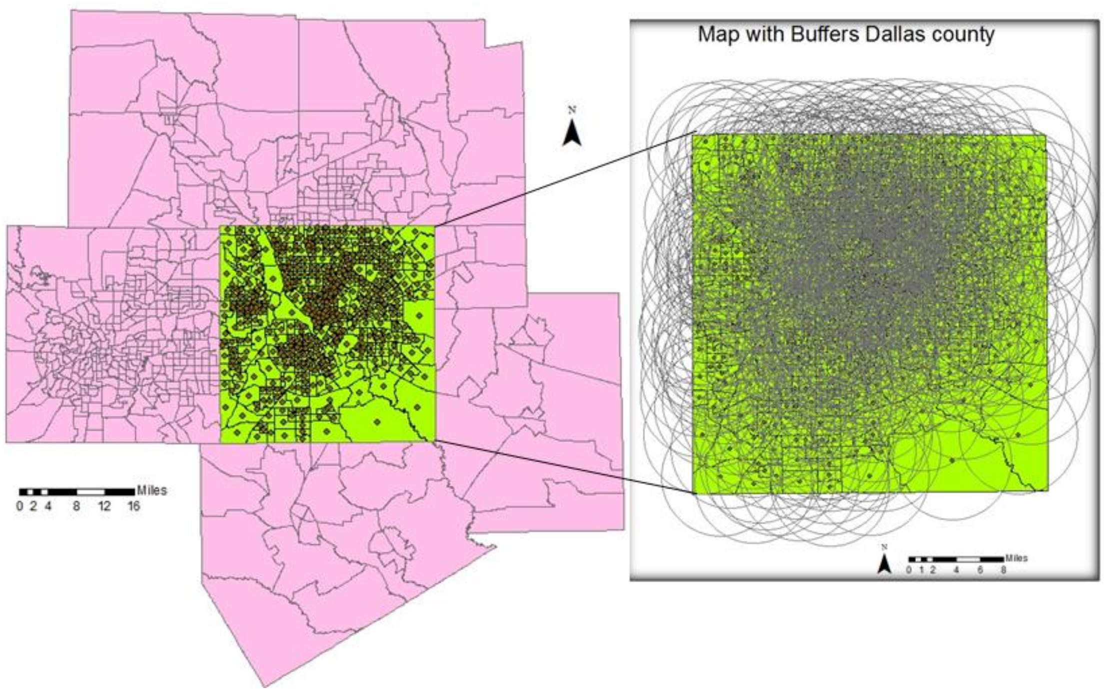


Figure 30 Maps showing generation and buffering of centroid of the census tracts

The resultant map was reclassified in Geographical information systems (GIS) so as to break up the J/H balance into four categories. Figure 31 shows J/H ratio maps elaborating the very housing rich (JH ratio less than 0.85), housing rich (JH ratio >0.85 but less than 1.2), balanced (JH ratio>1.2 but less than 1.7) and job rich areas (JH ratio>1.71). Overall GIS model in Figure 32 shows steps used to generate the final map.

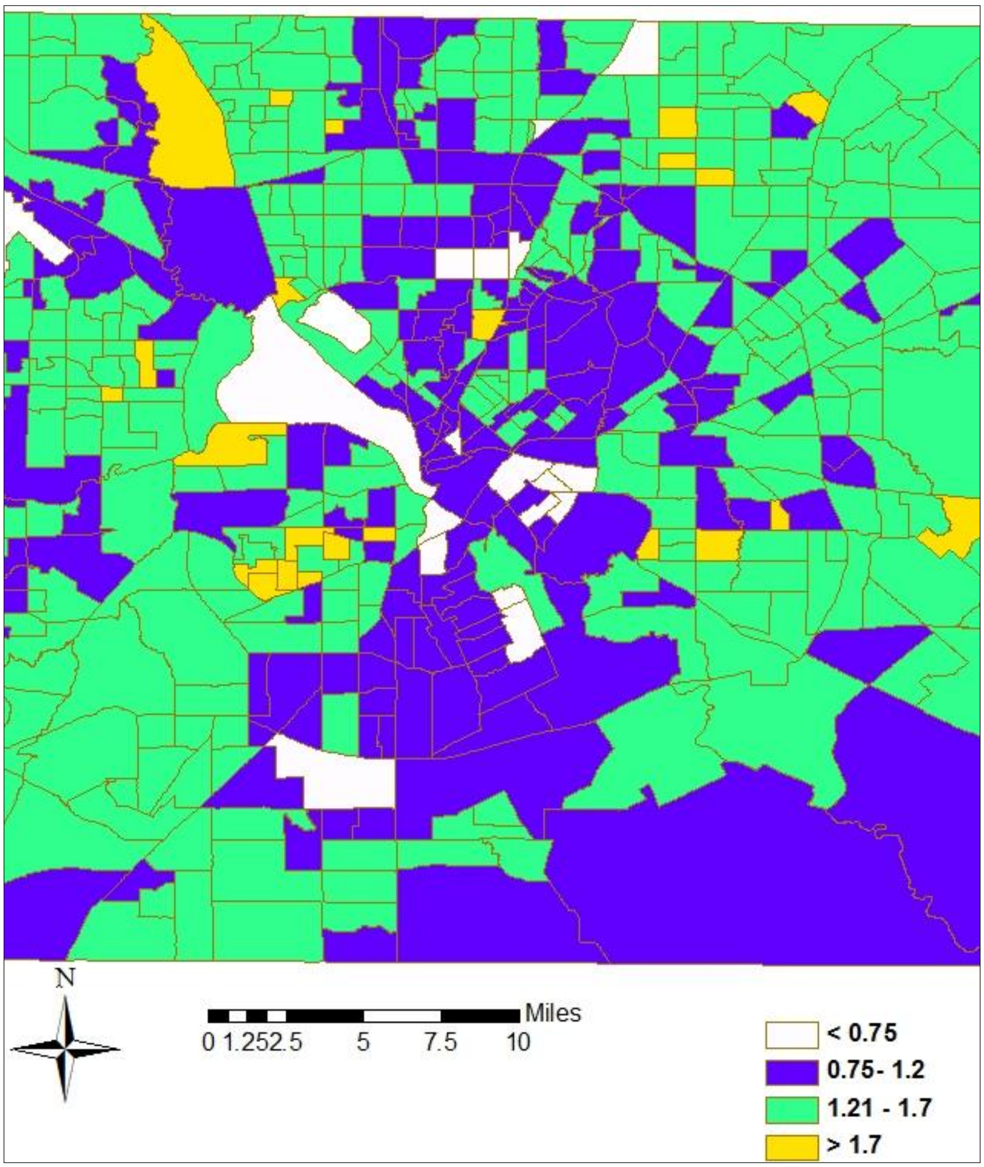


Figure 31 Census tract level map of Dallas County showing JHR

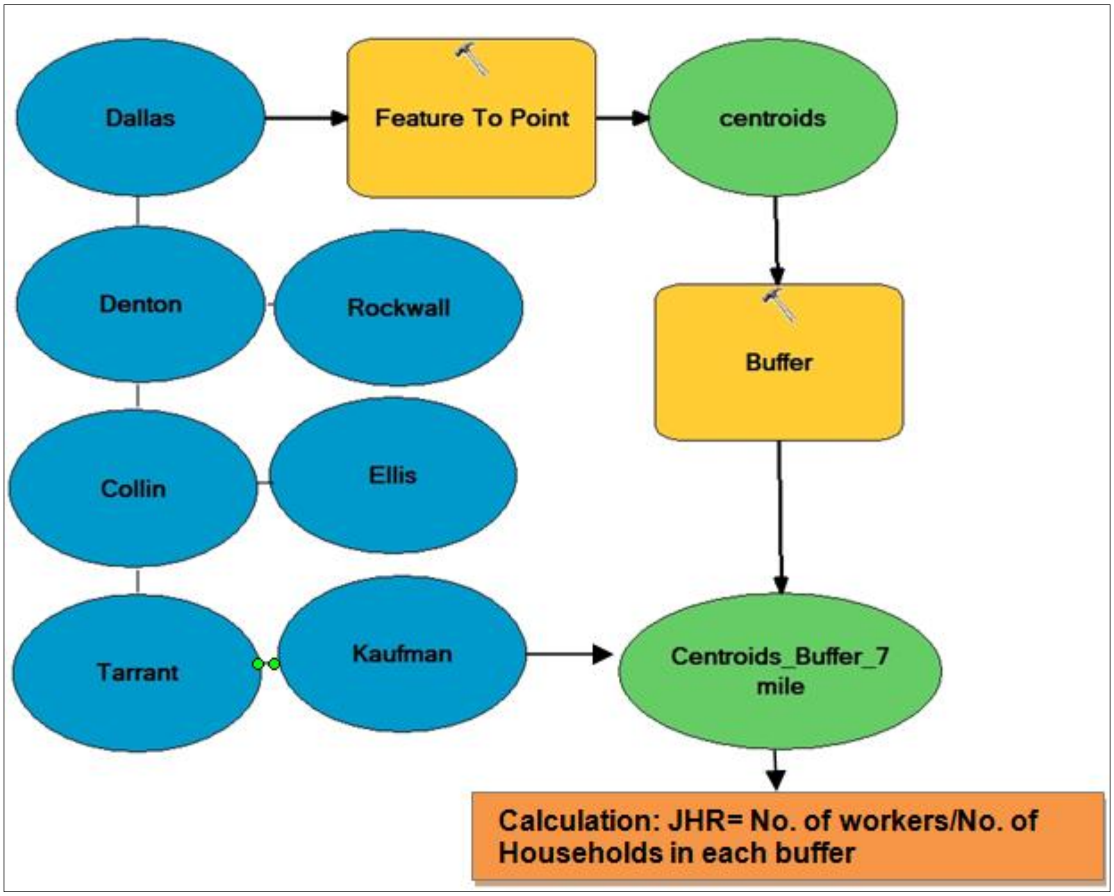


Figure 32 Overall GIS model to calculate the JHR for Dallas County

Next step is to determine the relationship between J/H ratio and mean time to work. Results in the form of Descriptives for ANOVA are shown in Table 13. The outcome provides mean time to work for each sub- category of J/H ratio as well as the mean time for the whole sample i.e. total for all the census tracts of Dallas County. There is a statistically significant difference among groups when analyzed by one-way ANOVA ($F(3,522) = 3.726$, $p = .011$). Tukey's post-hoc test also revealed that the commute time to work was statistically significantly higher for Very Job housing rich (27.36± 6.65 min, $P = .007$) when compared to Housing rich areas (24.5 ± 5.80 min, $P = .007$). However, there were no statistically significant differences between the rest of the groups including JH balanced areas (25.49 ± 4.1 min) and Job Rich areas 25.90 ± 6.24 min) (Refer to Table 13). As of now we know that their does exist a relation between J/H ratio and mean time to work but to move ahead with MLR it is important to determine the type of relation, for this purpose a "Curve Estimation Analysis" was conducted in SPSS. The output from curve fit test is presented in Figure 33 and Table 14, it is clear from the results that there is not a linear relation but a significant quadratic association between the two variables.

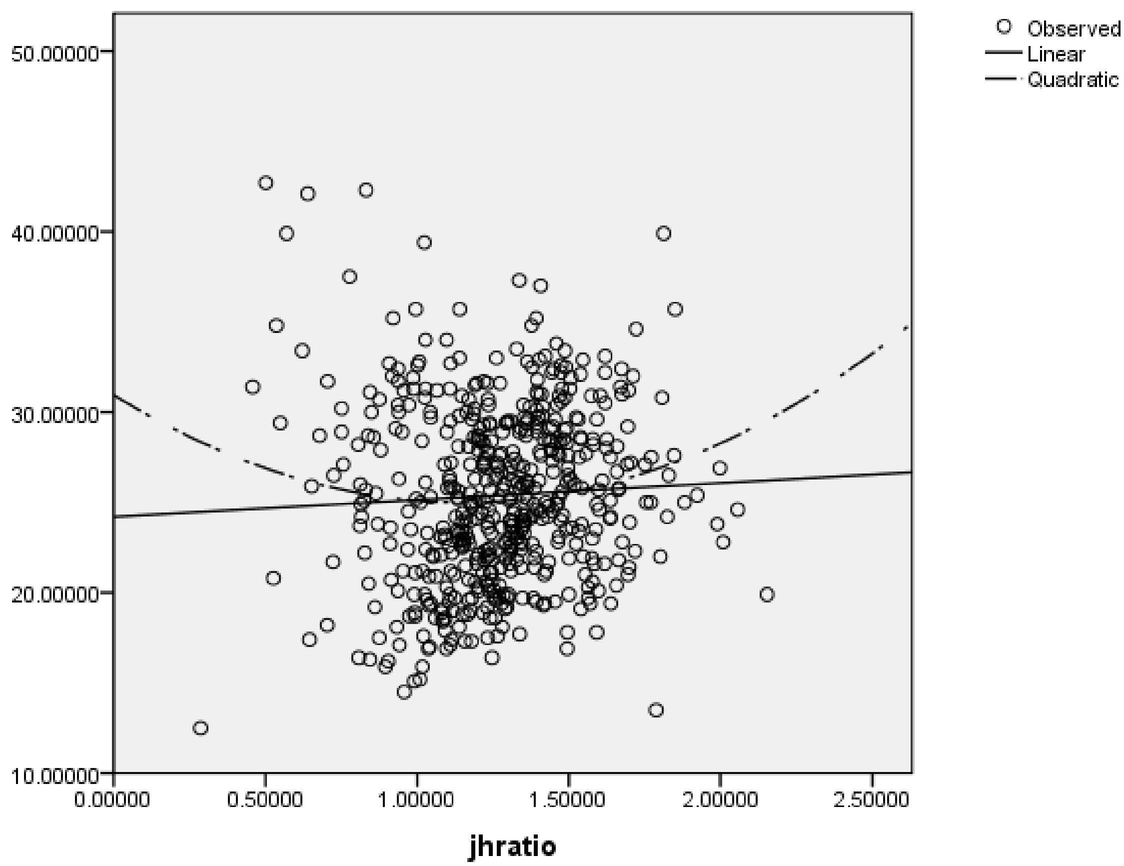


Figure 33 Scatter plot for curve estimation of j/h ratio and MMT

Table 13 Descriptives for one way ANOVA for JHR and MTT

Groups	Mean	Std.Dev.
V.Housing Rich (0)	27.36410	6.64663
Housing Rich (1)	24.46899	5.80160
Almost balanced(2)	25.49213	4.19833
Very Job Rich (3)	25.90670	6.23887
Total	25.39183	4.94331

Table 14 Curve estimation model summary for j/h ratio and MTT

Equation	Model Summary		
	R-Sq	F	Sig.
Linear	.003	1.359	.244
Quadratic	.014	3.640	.027*
D.V: Mean time to work I.V: J/H Ratio			

Curve estimation analysis concludes that the Mean time to work is high when the J/H ratio gets severely imbalanced i.e. less than 0.8 and greater than 1.7. Studies reveal that simple calculation and analysis of J/H ratio of total jobs to total households is not a satisfactory meter to gauge an imbalanced neighborhood. It is important that workers income should match the value of the house i.e. the available housing should be affordable to the worker, rich people mostly undertake longer commutes due to better quality housing in the suburbs and moderate/low-income workers have to travel more in order to find residence which fits into their budget (Cervero 1996). Hence, another explanatory variable, Housing Affordability Index (HAI) was computed. It is simply the median value of houses divided by the median income of workers for each census tract. This indicator checks the match between workers income and median value of houses. An HAI range of 3.5-5.5 is considered a balanced housing affordability level (Sultana 2002; Roundtable 2008). To check the relationship between MTT and HAI we again run ANOVA for HAI balanced and imbalanced census tracts in the County.

Table 15 ANOVA table for housing affordability index

Groups	**N**	**Mean Travel Time**	**Std. Dev.**	**Std. Error**
HAI Imbalanced (0)	387	26.249354	4.795	.24372001
HAI Balanced(1)	139	23.004317	4.567	.38740852
Total	526	25.391825	4.943	.21553848
F-Statistic= 48.017, Significant at p = .001				

Table 15 indicates that there is a statistically significant difference among groups when analyzed by one-way ANOVA ($F(2,526) = 48.087$, p = .011). The Mean Travel time for HAI balanced areas is significantly lower than HAI imbalanced areas. Giving another proof of Job Housing match as an efficient strategy to reduce wasteful commute. Figure 34 shows the GIS map representing housing affordability in Dallas County.

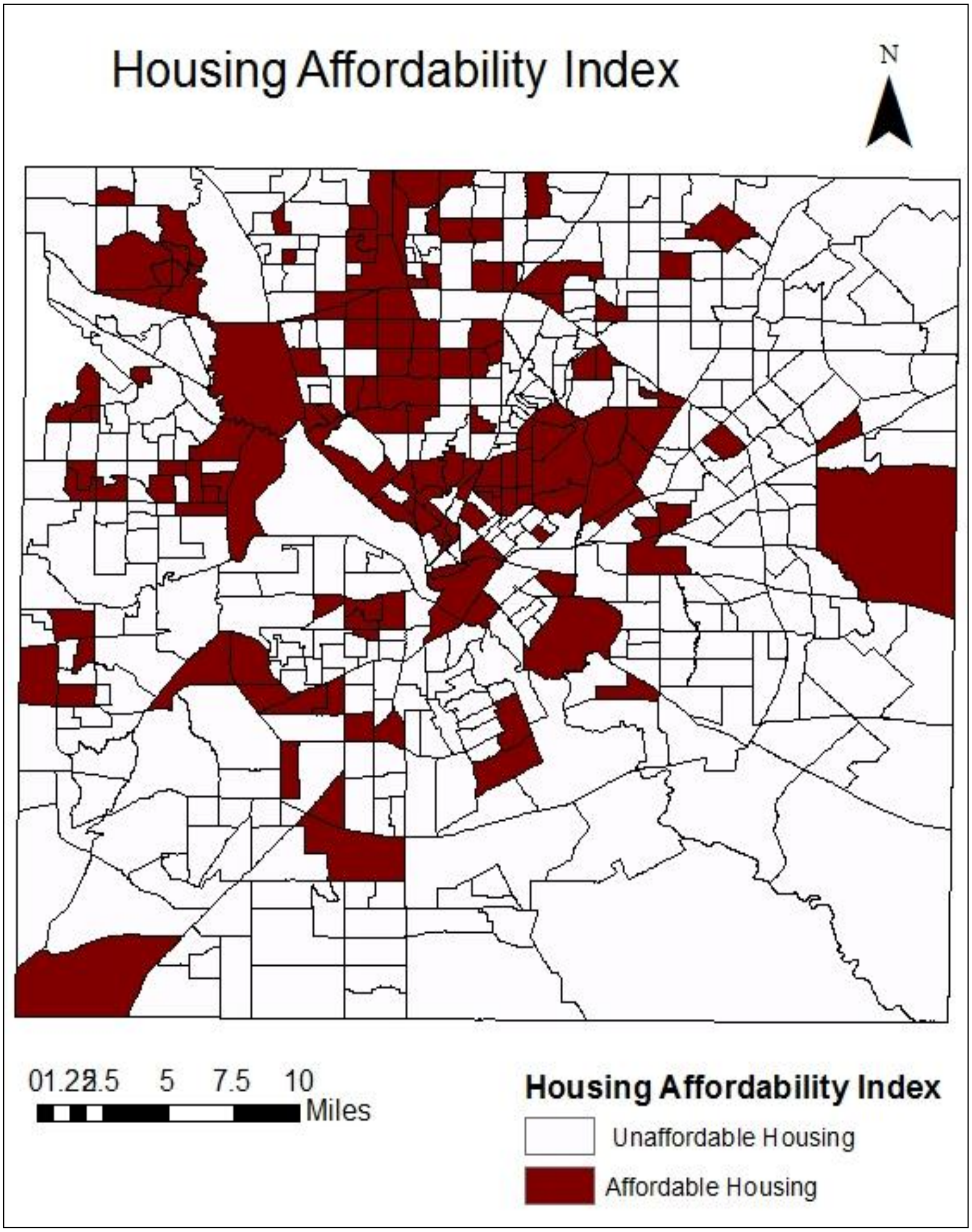


Figure 34 Map illustrating housing affordability index

6. CALCULATION OF ENTROPY SCORE FOR LAND USE MIX

Diverse measures have been used in the previous studies to measure landuse segregation and mixing. These include dissimilarity scores, gravity indices, and absolute clustering scores (Knaap, Song et al. 2005; Brownson, Hoehner et al. 2009). These options have been used by professionals working in a wide range of disciplines including land use ecology, urban sprawl, neo urbanism, smart growth, market share of firms etc. However, after checking the success rate of researches, this research uses the recently developed measure of entropy scores for our study (Brown, Yamada et al. 2009). Entropy scores were originally developed as variants of the Shannon index to investigate the precision of information transfer (Shannon and Weaver 1949). Afterwards they were modified to measure the uniformity of spread across various categories (Krebs 1999). In the formula “area” is the square feet of building floor area and the entropy scores is equal to one when land use is maximally mixed (equal mixes of the 6-categories) or heterogeneous and zero when land use is maximally homogeneous (Brown, Yamada et al. 2009).According to this technique, the measurement of landuse mix (variety of uses and accessibility) can be quantified and portrayed in the form of entropy index/score, this calculates the degree to which different types of land uses are dispersed within an area, in our case it is going to be determined with respect to the census tracts. The entropy index ranges from 0-1, with "0" representing homogeneity i.e. all uses are of single type e.g. commercial and "1" representing heterogeneity (the area under consideration has a well balanced distribution of all/most of the land use types). Initially, Frank came up with the three category mix, equation:

Equation 1. Three-category LUM

Land use mix= (-1)* [(b1/a)*ln(b1/a) + (b2/a)*ln(b2/a) + (b3/a)*ln(b3/a)]/ ln(n3)

where:

- a= total square feet of land for all three land uses present in buffer
- b1= residential
- b2= commercial
- b3= office
- n3= 0 through 3, summing the number of different land uses present

(Frank, Andresen et al. 2004)

But after identifying a few flaws in the 3-category formula, he modified it to the 6-category equation 2:

Equation 2 Six-category LUM

Land use mix= -A/(ln(N))

where area =

- A=(b1/a)*ln(b1/a) + (b2/a)*ln(b2/a) + (b3/a)*ln(b3/a) + (b4/a)*ln(b4/a) + (b5/a)*ln(b5/a) + (b6/a)*ln(b6/a)
- a = total square feet of land for all six land uses present in buffer

b1-b6 measure areas of land use for:

- b1= single-family residential
- b2= multifamily residential
- b3= retail
- b4= office
- b5= education
- b6= entertainment
- N= number of six land uses with area > 0.

Source: (Frank, Schmid et al. 2005; Frank, Sallis et al. 2006; Brown, Yamada et al. 2009; Hayley, Fiona et al. 2011)

As for the purpose of this research, the entropy scores were computed to represent land use mixes based on 6-category (2006) measures from Frank and colleagues. We also preserved the square feet area for each of the land use types used in each entropy score in the GIS attribute table. These 6-variable computations are measured up to their total respective entropy scores so as to sum up the equality of blending across the land use categories. The original landuse map downloaded from the NTCOG website had the following coding scheme shown in Table 16.

Table 16 Land use coding scheme by NCTCOG for GIS map

Code	Category	Land Use
111	Residential	Single Family
112	Residential	Multi-family
113	Residential	Mobile Homes
114	Government/Education	Group Quarters
121	Commercial	Office
122	Commercial	Retail
123	Government/Education	Institutional
124	Commercial	Hotel/Motel
131	Industrial	Industrial
141	Infrastructure	Transportation
142	Infrastructure	Roadway
143	Infrastructure	Utilities
144	Airports	Airports
145	Undeveloped	Parking Garage
146	Airports	Runway
147	Commercial	Large Stadium
160	Commercial	Mixed Use

Table 16 (Continued)

Code	Category	Land Use
171	Dedicated	Parks
172	Dedicated	Landfill
173	Undeveloped	Under Construction
181	Dedicated	Flood Control
300	Undeveloped	Vacant
306	Undeveloped	Parking (CBD)
308	Undeveloped	Expanded Parking
314	Undeveloped	Gravel
500	Water	Water

(Source: NuStats Report 2007)

In order to bring it under the six categories defined by Frank (2006), mixed use was brought under the collection of retail buildings and group quarters were summed up with office buildings. Hotel/motels and stadium were counted as entertainment buildings. Thus the recoded scheme is given in Table 17.

Table 17 Recoded land use scheme by the author

Code	Category	Land Use
111	Residential	Single Family
112	Residential	Multi-family
122 & 160	Retail/commercial/Mixed use	Retail
114 & 121	Government/Group Quarters	Office
123	Government/ Institutional	Education
124 & 147	Motel/Motel/Stadium	Entertainment

However, area under airports, water, parking, utilities, roads and transportation was not included in the analysis. Furthermore dedicated and undeveloped land was also not considered to calculate the entropy index for the land use. For the purpose of calculation of areas under each category of land use it was important to project the data, so I used "NAD 1983 State Plane Texas North Central FIPS 4202 Feet" as the projected co-ordinate system. This is Lambert Conformal Conic projection and the benefit for maps deploying this projection is that all angles are conserved and shapes (especially for the states near the reference parallels). Furthermore, there is least areal distortion for these states as well. The next step is to summarize the area under each land use, this was done in GIS using zonal statistics (tabulate area) from the spatial analyst tools. Census Tracts were given as the zone fields and land use type as the class field. The resultant table summarized the area under each category of the land use. Then the above mentioned formula by Frank (2006) was used to calculate the entropy index for each census tract, the follow-on map (Figure 35) gives the level of homogeneity/ heterogeneity of land uses within the county. Figures 36 and 37 give a closer snapshot of sample census tracts with maximum heterogeneity and homogeneity of land uses. As mentioned earlier, the census tracts with maximum heterogeneity get an entropy score of "1" and those with minimum get the score of "0".

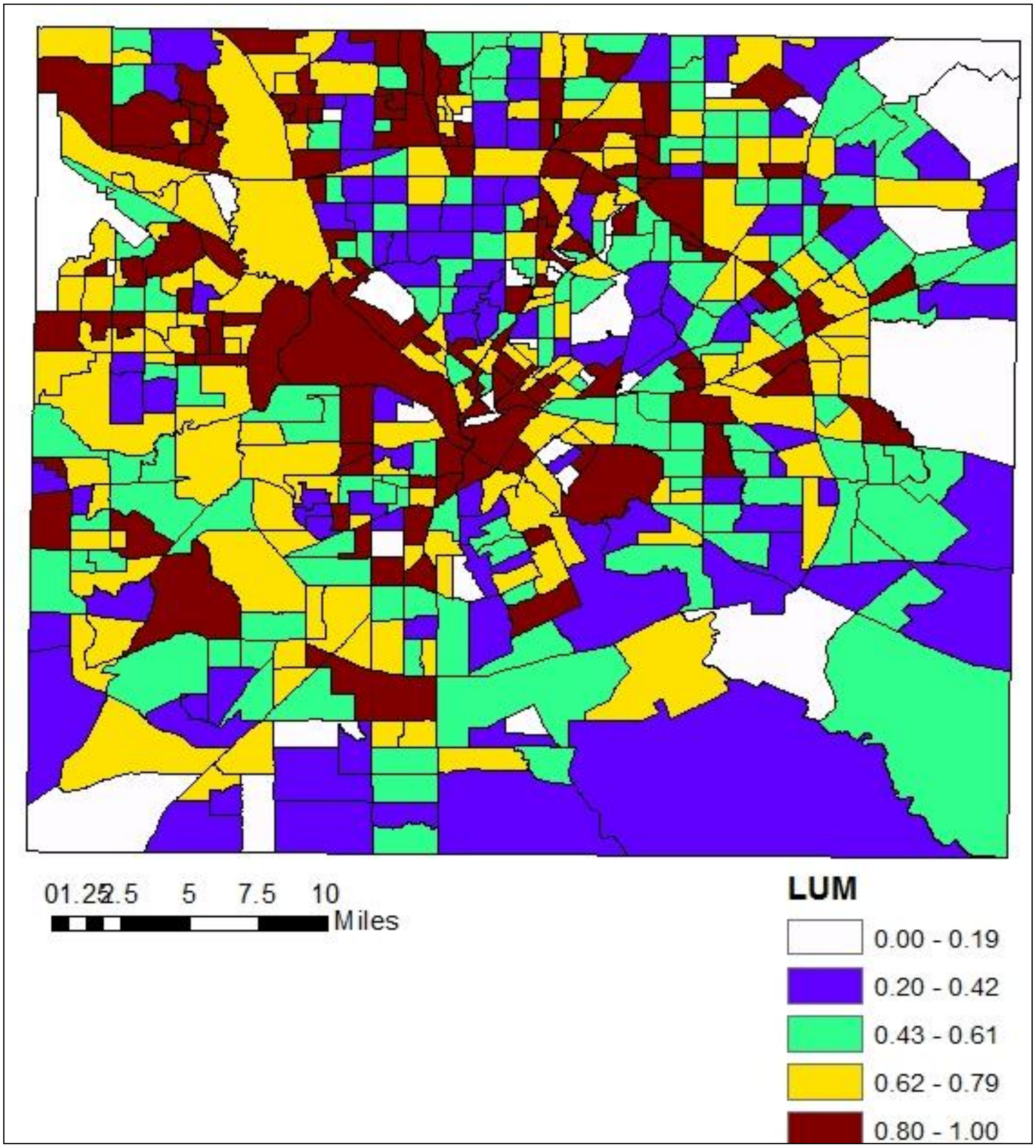


Figure 35 Map showing entropy scores for LUM in Dallas County

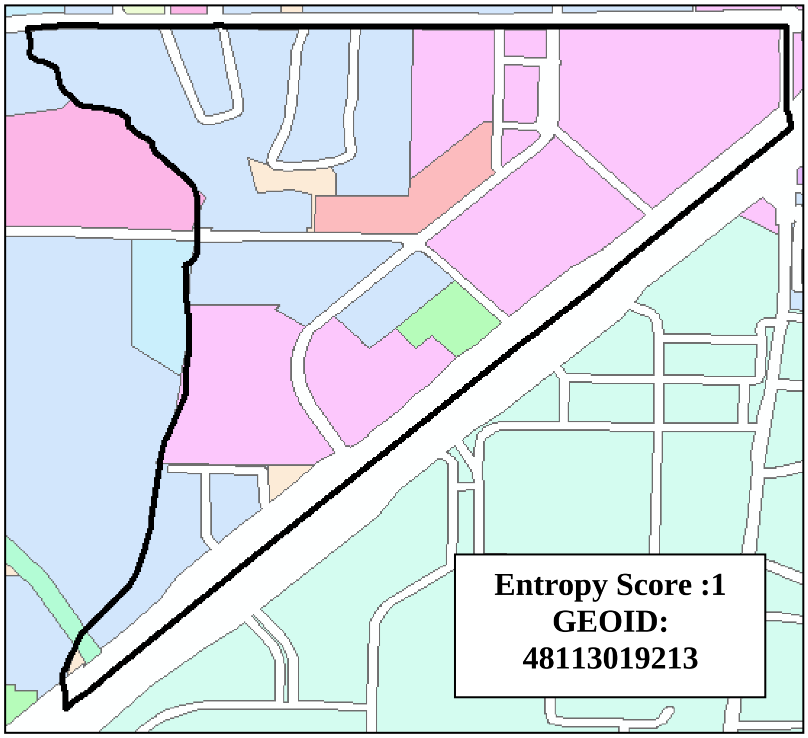


Figure 36 A sample census tract with maximum heterogeneity of land uses

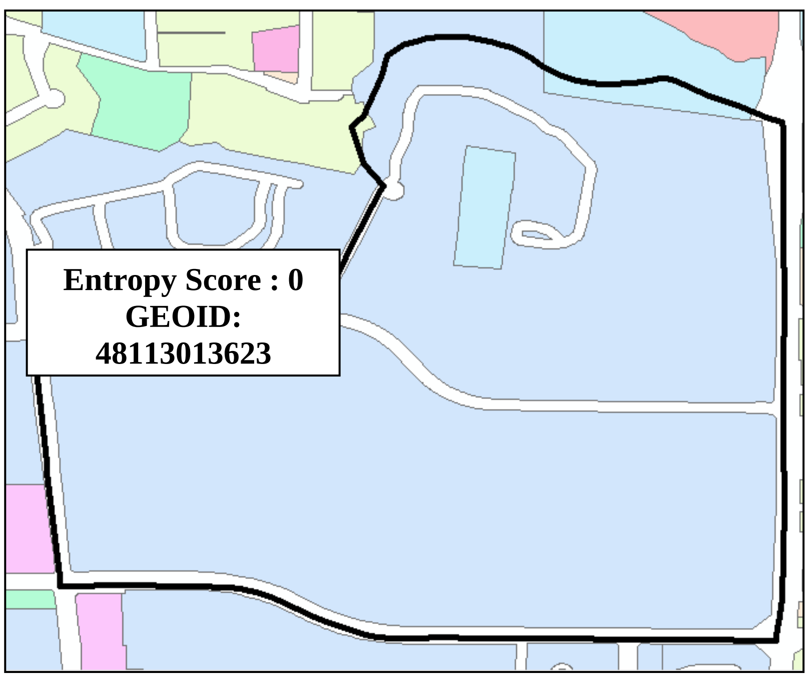


Figure 37 A sample census tract with maximum homogeneity of land uses

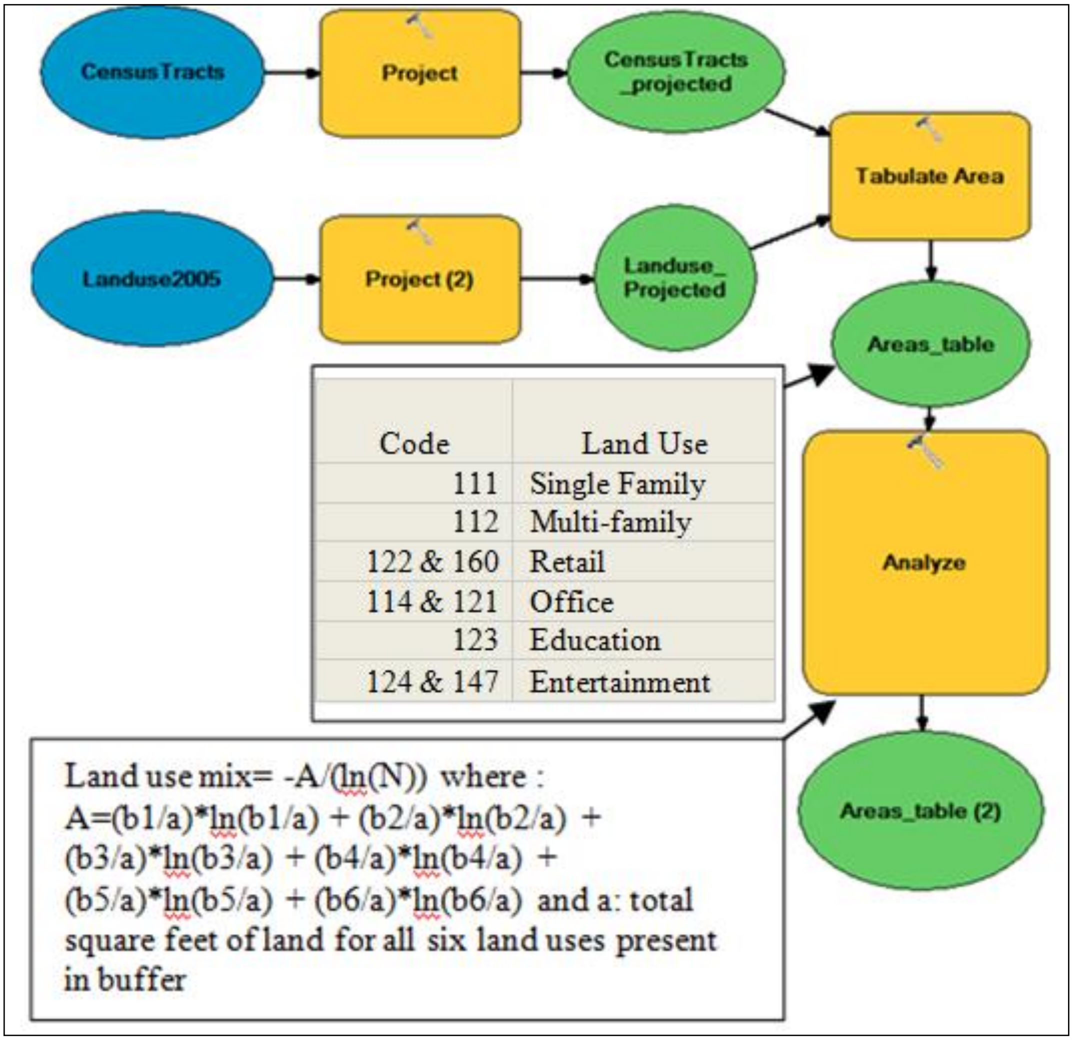


Figure 38 Overall GIS model to calculate the entropy score of land use mix

The Land use mix formula was applied to the areas table, in order to get the entropy squares for land use mix within each census tract. Areas Table 2 now shows the level of LUM in the study area. Figure 38 gives the overall GIS model to achieve the same.

7. MULTIPLE LINEAR REGRESSION (MLR)

In this section we will formulate the MLR Hypothesis, discuss the Dependent and Independent variables and presents the results. The Modus operandi to validate the following research hypothesis is hereunder:

"Land use mix, *Job-Housing Ratio and Housing Affordability Index (HAI), are statistically significant predictors of commute time to work controlling for the socio-economic and travel characteristics of the workers".*

Census tracts are used as a geographic unit of analysis, and U.S. Census Data aggregated to census tract level is used for the study. The dependent variable is "Mean time to work" and the independent variables include socio-demographic variables (median age, ethnicity, gender, education level, and household size etc) economic variables (workers income, percentage below poverty level, median personal vehicles in a household, Housing affordability Index etc), travel characteristics (mode of travel etc), J/H ratio and Land use mix. The regression equation for MLR becomes:

Equation 3

Mean Time to work = a + b1 (Log White) + b2 (Log Black) + b3 (Log Public Transit) +b4 (Log Walk) + b5 (Educ. Bach. Above) + b6(Median Age) + b7(HH size) +b8 (Male Worker) + b9 (J/H Ratio)+ b10(J/H Squared)+ b11 (Housing affordability)+b12(Land use Mix)

The major assumption of MLR states that the variables should exhibit multivariate normality i.e. the variance should be the same for each expected value (homoskedasticity). In our data some of the factors were skewed, so it became significant to transform the data to a symmetric distribution (Myers 1990; Cohen 2003). This allowed data to meet the assumptions of MLR more closely and accurately. Additionally, it enhanced the interpretation or appearance of related graphs. Logarithmic function was applied to transform some of the variables describing race (white & Black), mode of travel (Public transport & walk) and education variables (Bachelors and above). Furthermore, the relation between J/H ratio and commute time to work is non-linear or quadratic. So we have to put in another variable into the regression i.e. J/H-squared in addition to JH ratio and it is obviously computed by squaring all the values of JH ratios, this is to satisfy the requirements of quadratic relations following the parabola instead of the linear relation in MLR. The trick is that we are making a new predictor by squaring another predictor. The new squared predictor (J/H squared) has a linear association with Y (MTT).The model R^2 is 0.617, meaning we are now accounting for about 61.7% of the variation in mean commute time to work or in more specific words, the results of best MLR model suggest that the socioeconomic and travel characteristics of workers together with J/H ratio, HAI and land use mix, explain about 62% variation in "MTT to work". The usefulness and validity of the model was confirmed by F-Statistic 38.230, which was found to be significant at P-value of 0.001. The explanatory variables such as white workers, walk as travel mode to work, workers having education level of bachelors and above, and HAI were found to be statistically significant predictors of the dependent variable and have an inverse relation with MTT. However, Black workers, public transit as travel mode to work, household size, male worker and median age have direct significant relation with MTT. These findings led to the authentication of our research hypothesis that land use mix, J/H ratio and HAI are all statistically significant predictors of commute time to work. The model summary, ANOVA results and coefficients are given in the Table 18.

Table 18 Regression results for mean time to work

Model	**Unstandardized Coeff.**		**Beta**	**t**	**Sig.**
	B	**Std. Error**			
(Constant)	15.185	4.003		3.7933	.000
Log White	-.958	.357	-.143	-2.259	.025
Log Black	1.304	.179	.384	7.275	.000

Table 18 (Continued)

Model	**Unstandardized Coeff.**		**Beta**	**t**	**Sig.**
	B	**Std. Error**			
Log Public Transit	.812	.216	.161	3.761	.000
Log Walk	-.781	.214	-.150	-3.652	.000
Log Educ. Bach. Above	-1.263	.306	-.298	-4.131	.000
Median Age	.103	.040	2.574	2.574	.011
HH size	1.880	.505	3.724	4.478	.000
Male Worker	.001	.001	.154	2.600	.010
J/H Ratio	10.851	4.161	.621	2.607	.010
J/H Squared	-4.497	1.607	-.648	-2.799	.005
Housing affordability	-1.033	.427	-.107	-2.420	.016
LUM	-1.904	.817	-.097	-2.331	.020
R-square=.617. F= 38.230, significant at .001 level. Dependent variable: Mean travel time to work.					

7.1 Interpretation of the regression coefficients

With the variables log transformed, you lose the easy interpretation where a one unit change in the predictor is associated with a B unit change in the Dependent variable, partialing all other predictors. From the regression table it is clear that our five independent variables are log-transformed. However we can easily interpret the signs, i.e. More white people are associated with shorter commute times (negative B) and More black people are associated with longer commute times (positive B) ceteris paribus other variables remain the same. Additionally, workers using public transit as mode of travel to work, are associated with longer commute times (positive B) likewise those who walk to and from their work place , are associated with shorter commute times (negative B), controlling for the other explanatory variables. Workers having education level bachelors and above are associated with shorter commute times (negative B) holding other things constant. As in this case, the dependent variable (MTT) is in its original metric and five independent variable log-transformed (White, Black, Public transit, walk and education Bach & above. Here we can say that a one percent change in the explanatory variable increases (or decreases) the dependent variable by (coefficient/100) divisions. The model interprets that a one percent increase in the population of whites would result in a decrease of (-.958/100) = 0.0958 minutes in MTT to work for a particular census tract, holding everything else constant. Similarly a one percent increase in the population of blacks would result in an increase of (1.304/100) = 0.01304 minutes in MTT to work for a particular census tract controlling for the other explanatory variables. Moreover, a one percent increase in the usage of public transit as a mode of travel to work, is associated with (0.812/100) = 0.00812 minutes increase in MTT to work and a one percent increase in walk to work, is associated with (-.781/100) = -0.00781 minutes decrease in MTT to work, *Ceteris paribus* the other variables. Finally a one percent increase in the people with Education (Bachelors and above) would result in a decrease of (-1.263/100) = 0.01263 minutes in MTT to work for a particular census tract, holding everything else constant.

The remaining variables are not in logged form so they are simple to interpret. For every one year increase in median age the mean commute time to work increases by .103 minutes. Similarly one unit increase in the household size is associated with 1.880 minute increase in the mean commute time to work. Also the male workers have slightly longer commute times than the female workers (regression co-efficient= 0.001) controlling for the other variables.

The one place to be careful is with the J/H coefficient. When predictor is entered both as a linear term and as a quadratic term, we have to be concerned with the order of each term. The order is the sum of the powers of predictors for each term e.g. J/H squared is of order 2, J/H ratio is of order 1 and intercept is of order 0). The highest order term in an MLR describes the entire regression curve; we call this an unconditional effect because it does not depend on anything else. Lower order points just describe specific points along the curve, we call them conditional effects because the depend on the higher order terms. Since there is a quadratic term in the model, the B for J/H

(10.851) tells the association when J/H is at its mean (since we centered it). The negative coefficient for the squared term means the quadratic curve is downward bending, so with increasing J/H from its mean, the association becomes more negative (it decreases from 10.851), and with decreasing J/H from its mean, the association becomes more positive (it increases from 10.851). This means that when the J/H ratio is below the mean MTT is more and when it is above the mean MTT is less .Additionally we can confirm that J/H is a significant predicator of mean commute time to work and ANOVA results indicate that MTT to work is less for J/H balanced areas.

Greater housing affordability Index is associated with shorter commute times (ceteris paribus other variables), indicating that those census tracts which offer greater housing affordability have a smaller mean commute time to work. Finally we come to the chief interpretation our research, which says that the greater Land use mixing is associated with shorter commutes (negative B). As we know that a “0" for LUM, represents homogeneity i.e. all uses are of single type e.g. commercial and "1" represents heterogeneity of land uses, thus regression results indicate that one unit increase in the LUM is associated with a 1.904 minutes decrease in the Mean time to work.

7.2 Model sensitivity tests

We have performed MLR, just with modified independent variables that maintain the linear nature of the parameters, so the model should satisfy the conditions of a linear regression. Hence, the model is tested empirically for normality by using graphical tools; this is done by plotting the fitted values against the residuals and by assessing the normal P-P plot of regression standardized residuals (Figure39). Additionally the normality of the data is checked by comparing the histogram (Figure 40) to a normal probability curve. The empirical distribution of the data resembles a bell-shaped curve confirming a normal distribution. Similarly the lack of fit to the regression line suggests a departure from normality but our normal probability plot follows the regression line identifying that the data is a normal curve with ignorable outliers.

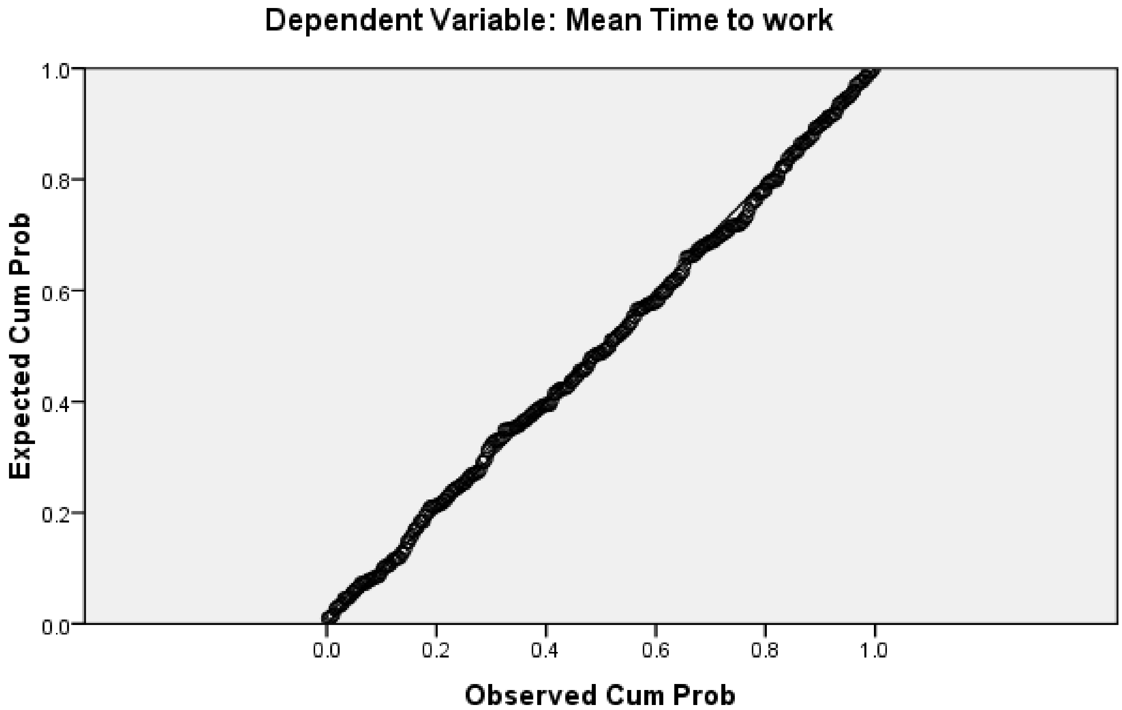


Figure 39 Normal probability plot of regression standardized residuals

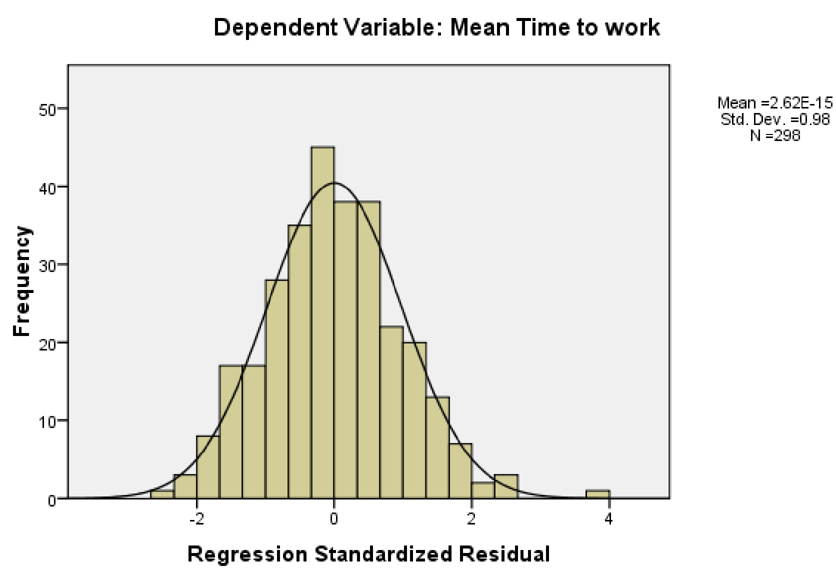


Figure 40 Histogram of regression standardized residuals

As a rule of thumb, some researchers' use 0.5 and others use 0.7 as a cutoff criterion for inter-correlations, from the matrix (Table 19) it is clear that none of the values exceed 0.5. Furthermore all the variables had tolerance value greater than 0.20, and Variance Inflation Factor (VIF) less than 5. All the tests reflects that none of the explanatory variables are highly correlated at .001 significance level (SPSS 2012)(Refer to Table 20).

Table 19 Collinearity statistics for the explanatory variables

Model	**Tolerance**	**VIF**
Log white	.335	2.985
Log black	.483	2.071
Log public transit	.738	1.356
Log walk	.795	1.257
Log educ. bach above	.259	3.863
J/H squared	.791	1.264
Landuse mix	.775	1.290
affordability	.689	1.451
Male worker	.381	2.626
Median age	.553	1.809
HH size	.297	3.372
J/H	.405	2.471
a. Dependent Variable: Mean Time to work		

Hence, we reject the null hypothesis which says that there is the problem of multi-Collinearity among explanatory variables.

Table 20 Inter-correlations matrix for explanatory variables

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.	-.233**	.565**	.252**	-.176**	-.378**	-.230**	.465**	.051*	.084*	-.383**	-.099*	.101*
2		1.	-.226**	-.153**	.026	.490**	.019	.127**	.407**	.539**	.020	-.073	-.347**
3			1.	.344**	.133*	-.095*	-.338**	.103*	-.159**	.218**	-.245**	.093*	.009
4				1.	.203**	-.108*	-.233**	-.026	-.072	.195**	.059	.141**	.117*
5					1.	.117*	-.243**	-.217**	-.003	.191**	.082	.237**	.034
6						1.	.427**	-.541**	.035	.423**	.230**	-.125**	-.349**
7							1.	-.385**	-.163**	-.158**	.056	-.270**	-.067
8								1.	.496**	.133**	-.384**	-.162**	.061
9									1.	.437**	-.288**	-.082	-.084
10										1.	-.066	-.032	-.202**
11											1.	.206**	-.023
12												1.000	.054
13													1.000

1. Mean time to work 2. Log white 3. Log Black 4. Log public transit 5. Log walk 6. Log Education Bach. above. 7. Median Age 8. HH size 9. J/H ratio

10. Male worker 11. HAI 12. LUM 13. J/H-Squared.

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

Next we examine the data for serial auto-correlation, as the auto correlated errors in regression may result in inefficient estimates of regression co-efficient, sub-optimal regression equations and usual significance test on the coefficients being invalid (Granger and Newbold 1974). Durbin Watson test for autocorrelation gives a DW-constant (d = 1.727), this means that there is no/negligible serial auto correlation (Table 21). Whilst d is near 2 there is no autocorrelation, thus observations under study are independent of each other. (Durbin and Watson 1950; Durbin and Watson 1971)**.** Value of *d* ranges between 0-4, however when Durbin–Watson statistic is < 1.0 there is positive serial auto correlation indicating that the value of consecutive error terms are pretty close to each other. However, if the value of d is greater than 2 consecutive error terms have very different values from each another.

Table 21 Durbin Watson test of serial autocorrelation (Model Summary[b])

R	*R Square*	*Adj. R Square*	*S.E*	*Durbin-Watson*
.785[a]	.617	.601	2.902	1.727
a. Predictors: (Constant), male, black, HH size, walk, public transit, median age, JH-Squared, white, Educ. Bach. above, JH ratio, Housing Affordability, Land use mix b. Dependent variable: Mean time to work				

8. TARGET AREA ANALYSIS

After the JHR, HAI and LUM analysis, we can now perform a suitability analysis which gives us the high priority areas and low priority areas to target as far as our remedial policy measures are concerned. As a step towards sustainable urban future, efforts should be geared to bring in the right J/H balance, LUM and Housing affordability level. Next we perform target area analysis in GIS to identify the action areas, under greatest stress of wasteful commute and related ills. Following is the modus operandi adopted:

- Preparation of shape files for JHR, LUM, MTT and HAI for Dallas County.
- Data is then projected into NAD 1983 State Plane Texas North Central FIPS 4202 Feet having Lambert Conformal Conic projection.
- All the four shape files are now converted into Raster data
- After that Spatial Analyst tools in GIS are used to reclassify the above mentioned raster files. Next step is to perform an overlay analysis. Since the measurement criterion for layers is different from one another e.g. the numbering systems have different ranges like LUM ranges from 0-1 and HAI ranges from '1-5'. Thus it is essential to combine them in a single scrutiny. To achieve this every cell for each variable is reclassified into a common preference scale such as 1 to 10, with 10 being the most favorable and 1 being the least acceptable. Therefore, the four raster files are reclassified on equal intervals from a range of '1-10'. Mean time to work is reclassified from '1' to '10', '1' being the maximum commute times (least favorable) and 10 being the lowest commute times (most favorable). Similarly LUM is recoded with '1' (least favorable) being the least mix of land uses and '10' being maximum entropy scores for land use mix(most favorable) and so on.
- Finally we apply the overlay tool and got the combined scores to identify low priority and high priority areas in need of policy reforms.

In our analysis we have given equal weights to all the indicators, however we can also use Weighted Overlay tool, when we have a multi criterion objective in mind. In that each of the criteria may not be of equal substance. We can weigh the important measures greater than the other criteria. At the end input criteria are multiplied by the weights and then summed up. The sketch in Figure 40 shows the overall GIS model adopted for target area analysis and Figure 42 gives the spatial overlay for the same.

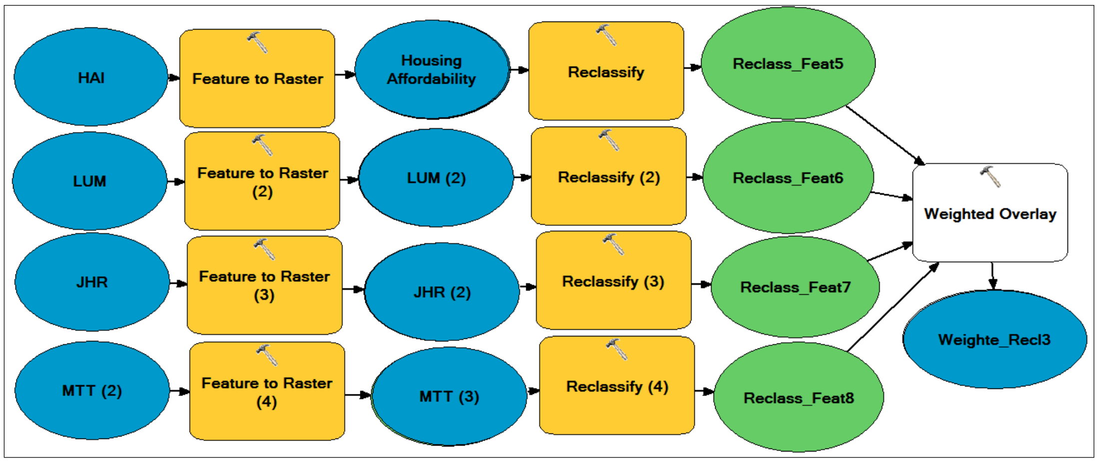


Figure 41 Overall GIS model for target area analysis

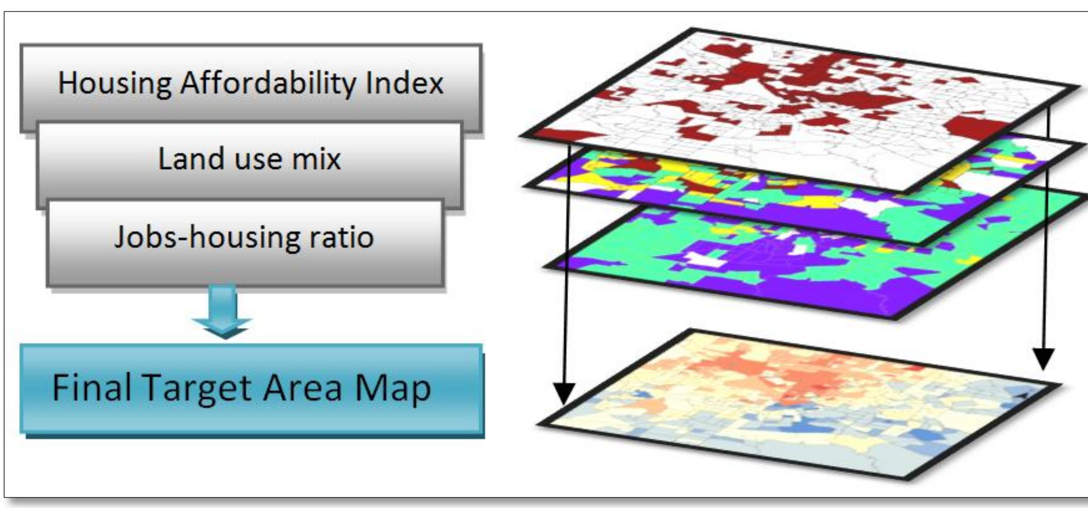


Figure 42 Spatial overlay for target area analysis

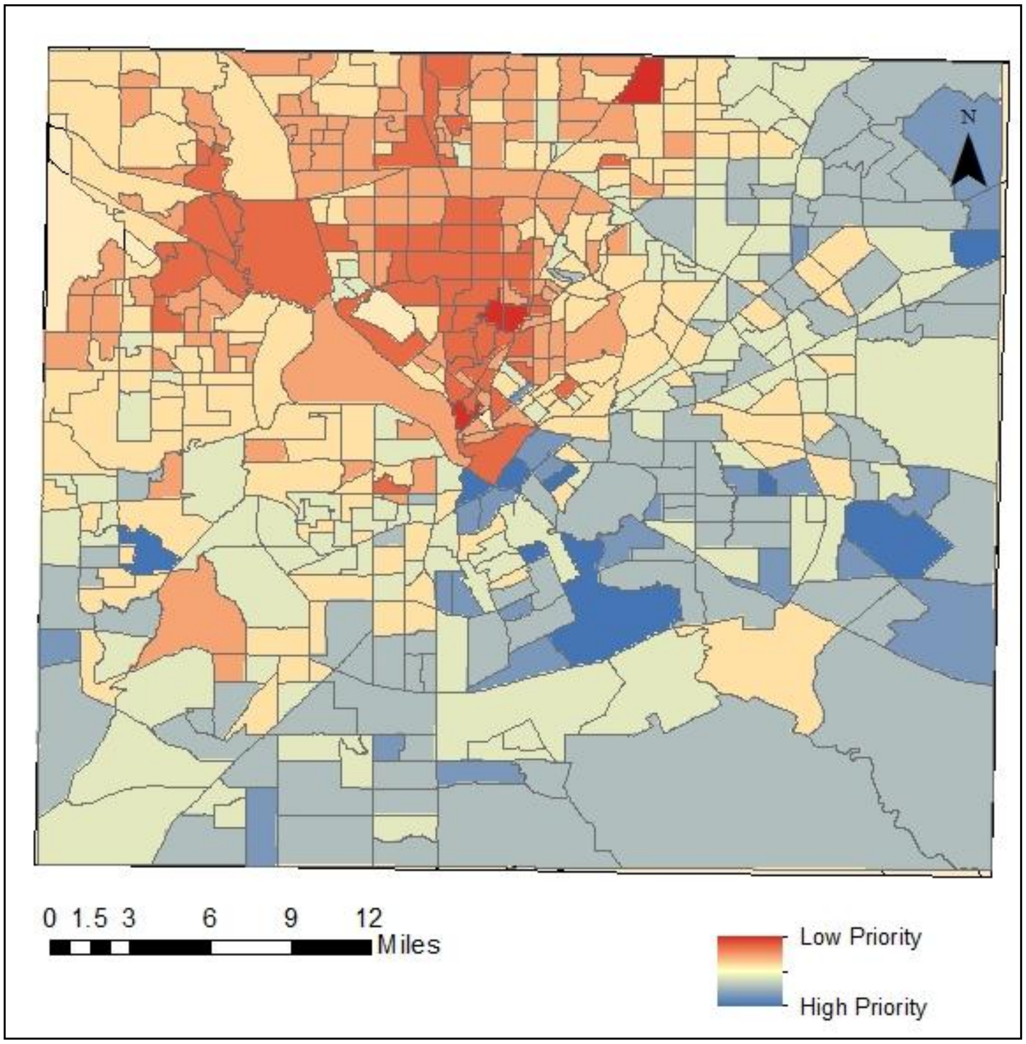


Figure 43 High and low priority target areas

Figure 43 gives the resultant map from the overlay analysis depicting high and low priority areas. The spatial picture indicates that Irving, Coppell, Carrollton, Richardson, Farmers Branch, University Park and North west Dallas city area are found to be low priority areas (under less stress score), as they are already doing well on the scales of measures adopted for this analysis. However, cities like Grand Prairie, Hutchins, Desoto, Cedar Hill, Mesquite, Garland, Rowlett, Seagoville, Lancaster and Glen heights are in a greater need of land use reforms.

9. ANALYSIS OF PUBLIC TRANSIT TRIPS (DART DATA)

This section of the research uses the 2007 Transit Rider Survey data by DART. NuStats conducted an origin/destination survey of the riders of Dallas Area Rapid Transit (DART). The self-administered surveys were conducted on fixed-route bus riders as well as Light Rail and Trinity Express railroad riders of DART. Data collection was conducted from April 4 through May 24, 2007. A total number of 7,813 completed and usable surveys were retrieved. The survey questionnaire was intended be a self-completion instrument with 25 principally self-coded inquiries. The survey was devised to elicit information in three key groupings: origin/destination data, access and egress modes, and rider socio-economic characteristics. It was developed to accommodate two languages, English and Spanish. (Refer to Appendix A for the English version of the survey Instrument and Appendix B for the coding scheme of the same). Information was extracted for origin, destination, trip purpose, access mode, egress mode, bus routes and rail lines used, number of transfers for one-way trip and the total distance travelled (NuSTATS 2007). However, for our research we have just considered the work trips made by the DART riders. Out of 7,813 surveys, 3,391 surveys were extracted for the purpose of this research as they were Home based work trips. Non-home based work trips and home based other trips were not considered for this analysis.

9.1 GIS analysis

The survey responses were put into the GIS environment. The origin addresses were geocoded onto the Dallas County map. The results are as shown in the map. The excel table carrying all the trip makers characteristics like age, sex, income, household size, number of vehicles in the house hold etc is attached to these events' shapefile (Refer to Figure 44). It also carries information about the trip characteristics like distance covered, transfers made, bus-only riders, rail-only rider, travel time etc.

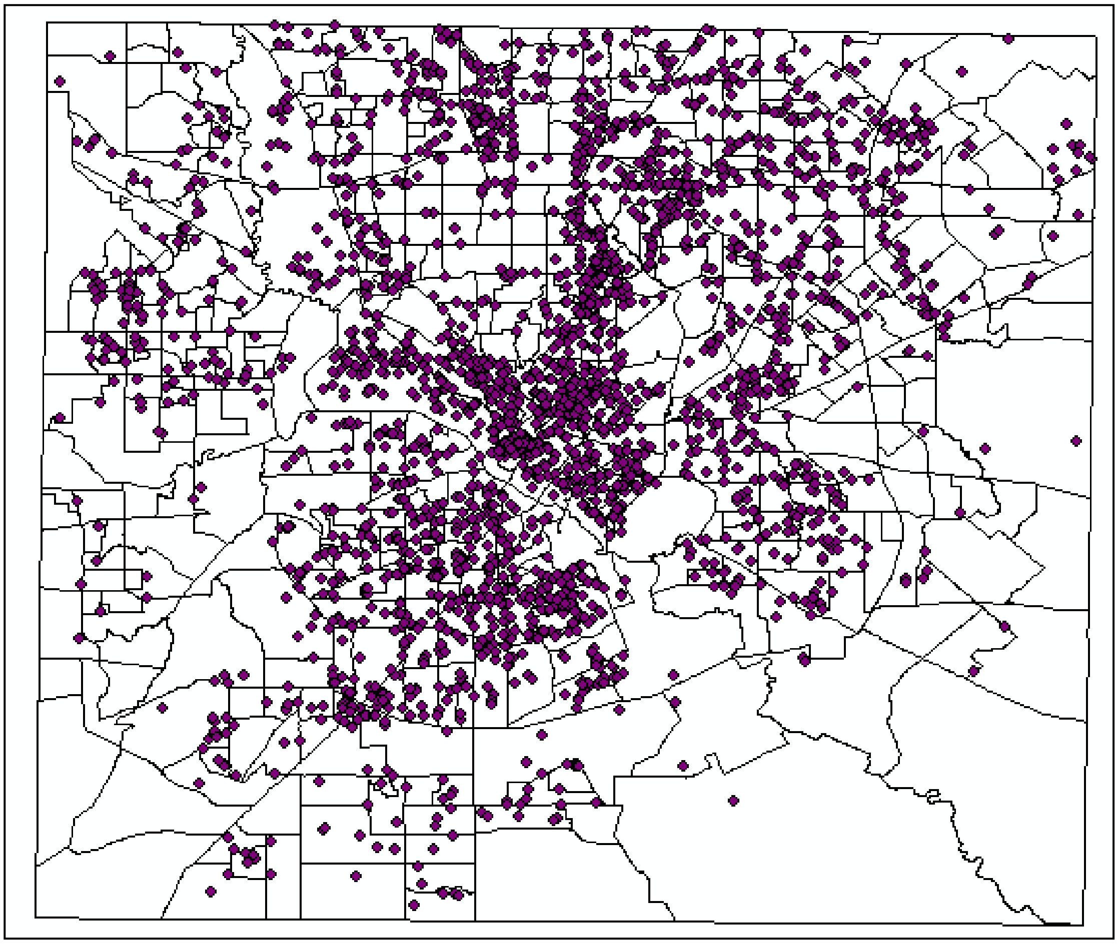


Figure 44 Geocoded events shapefile of DART survey data

Next, these points were interpolated by using the Inverse Distance weighting (IDW) from Geo Statistical Analysis tools in GIS with Trip Distance as the Z value field, to give us a better picture of the characteristics of trips made from different parts of the county by the public transit users. *"IDW interpolation technique approximates the cell values in a raster from a set of sample points that have been weighted so that the farther a sampled point is from the cell being evaluated, the less weight it has in the calculation of the cell's value*" (Zald, Summer et al. 2006).

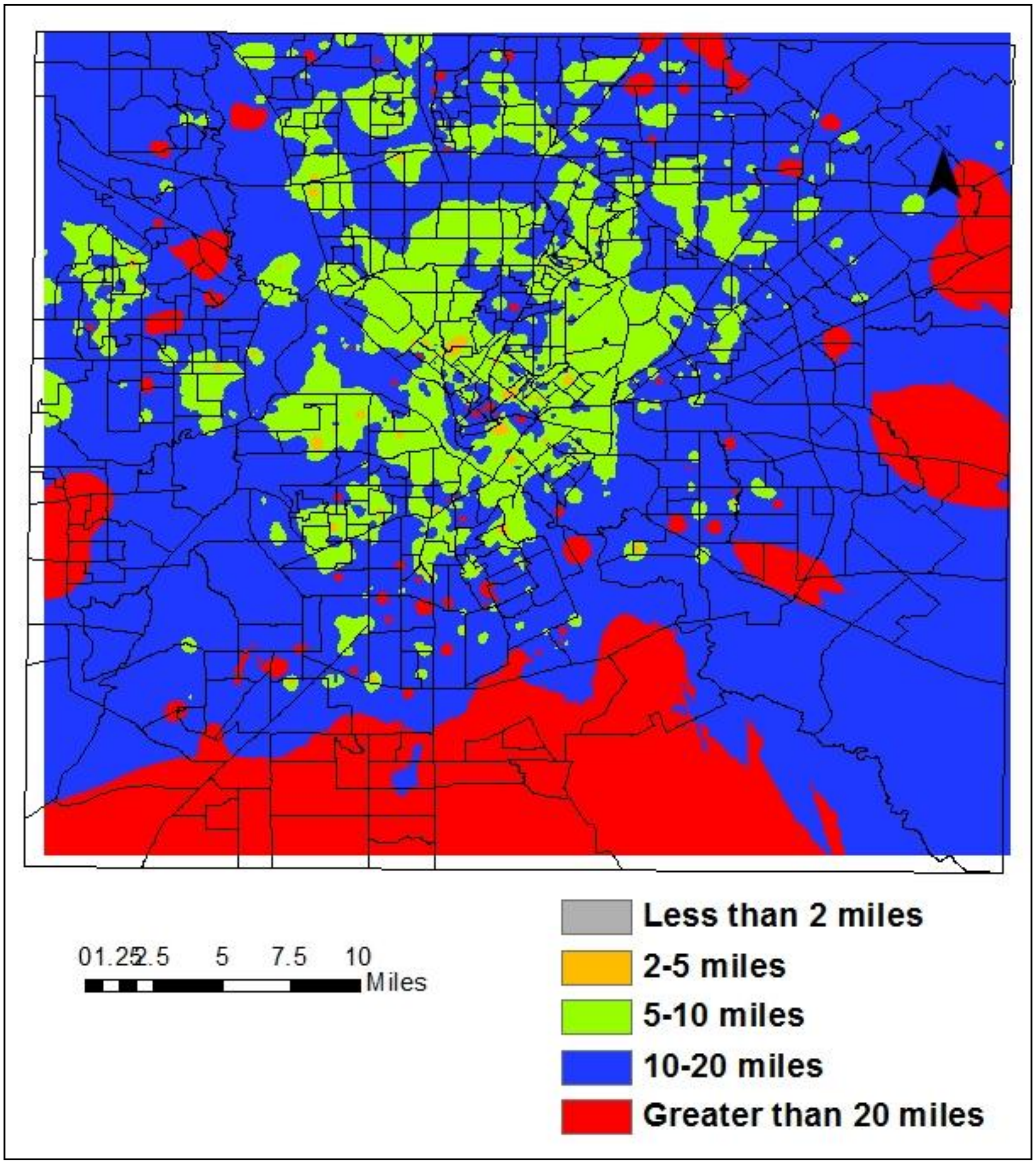


Figure 45 IDW interpolated map showing the distance covered by hbw trips

Figure 45 shows that the central core of county has comparatively shorter work transit trips and the longer ones are to and from the southern parts of the county.

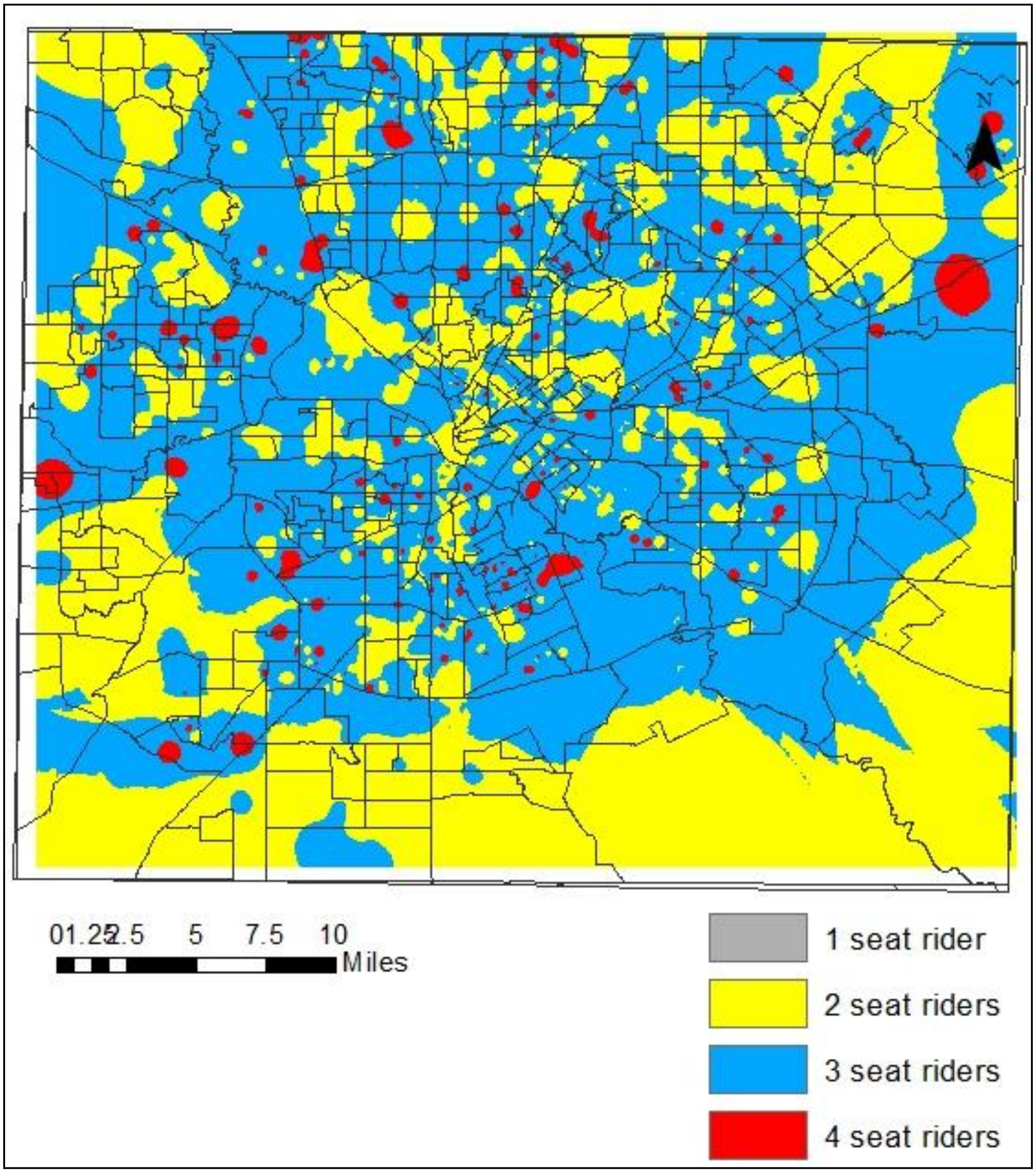


Figure 46 IDW interpolated map showing the number of transfers made by transit

It is interesting to note that most of the riders are 3 to 4 seat riders i.e. they have to make at least 2-3 transfers to complete a trip to work (Refer to Figure 46).

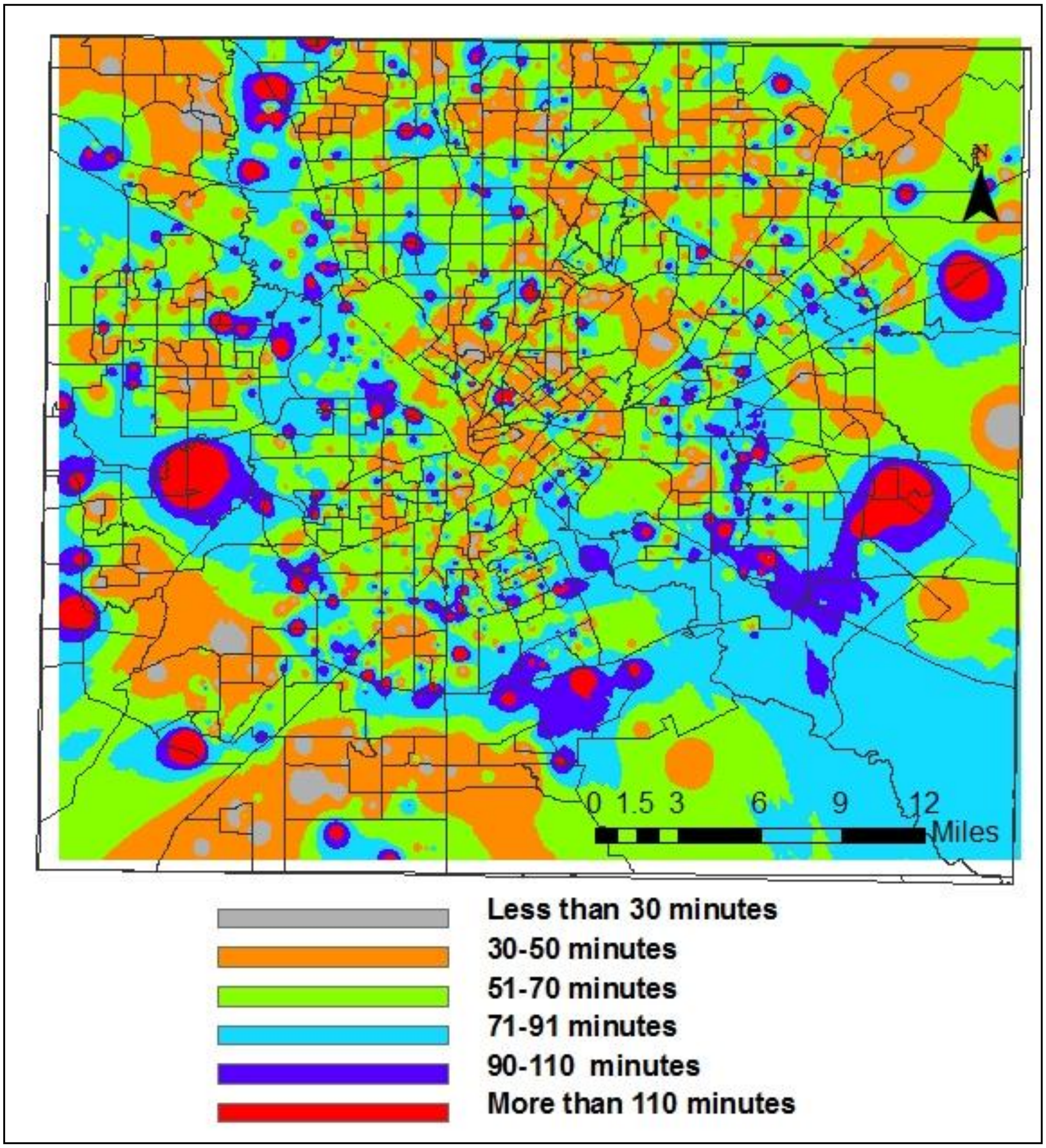


Figure 47 IDW interpolated map showing time spent in hbw trips

Figure 47 indicates that travel time to work by transit gives a different picture when compared to the travel distance variable for the same. The trip times do not show a definite trend. However we can still conclude that trips are longer both in terms of time and distance, in the southern parts of the County.

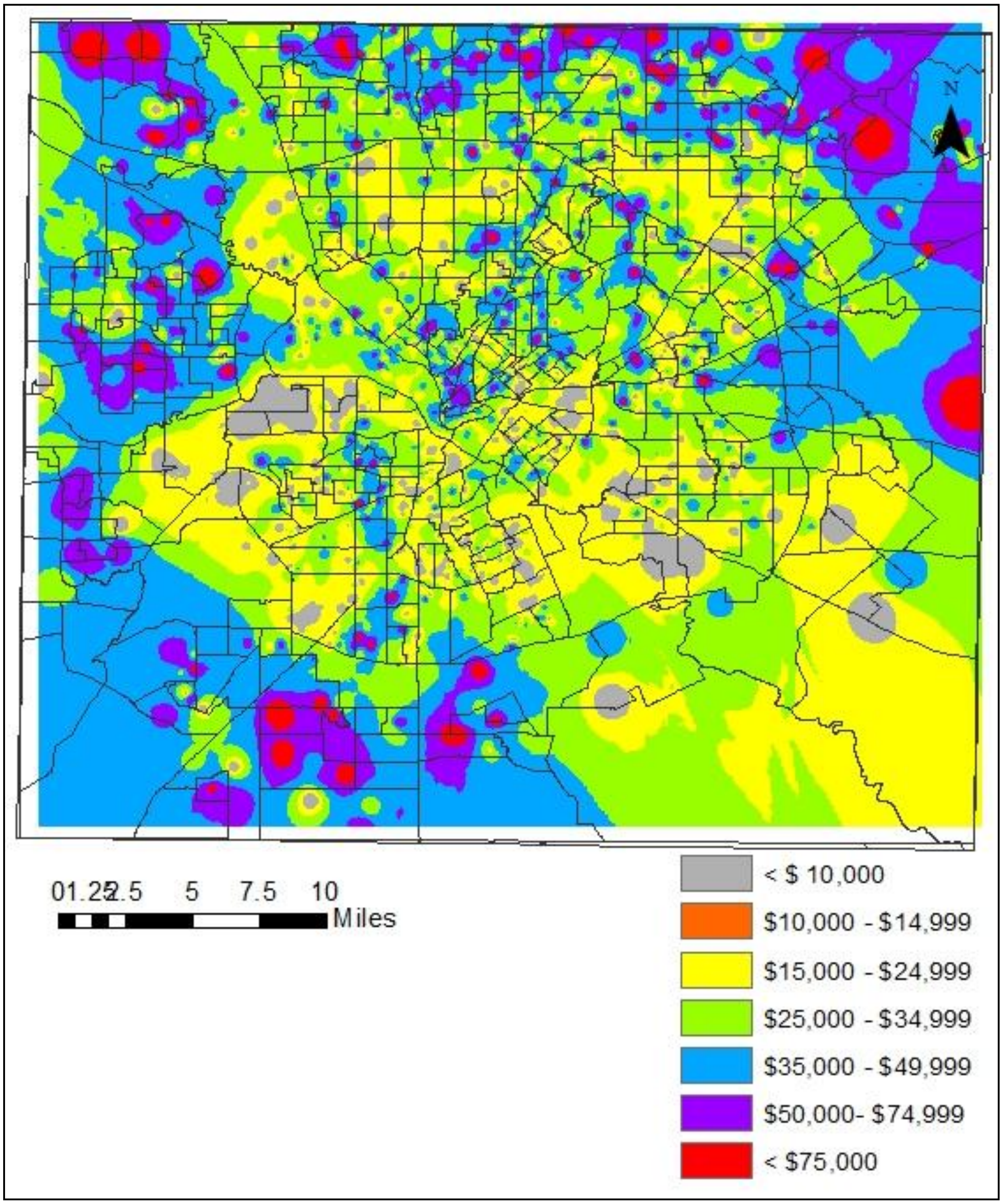


Figure 48 IDW interpolated map showing HH income of hbw trip markers

The economically disadvantaged transit users reside mostly in the centre and the south eastern sections of the Dallas County (Refer to Figure 48).

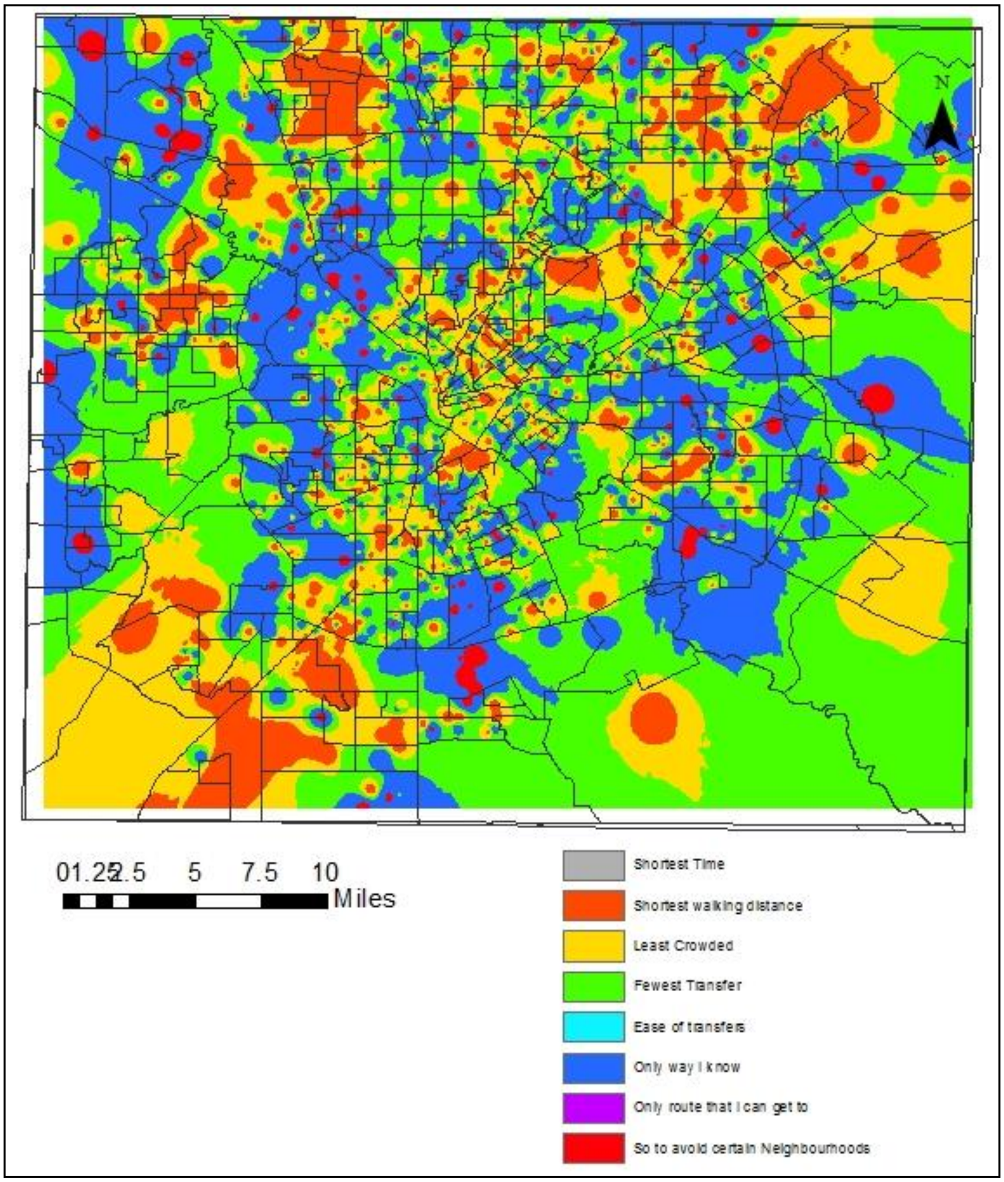


Figure 49 IDW interpolated map showing reasons for the selection of a particular transit route for the work trip

Map in Figure 49 shows the reasons for selection of a particular transit route to work. 'Fewest transfers' and 'the only way a trip maker knows' are the most common responses in the category. However passengers from the north east and southwestern parts of the county, seem to give more priority to the options of ' least crowded routes' and 'shortest walking distances to the stop'

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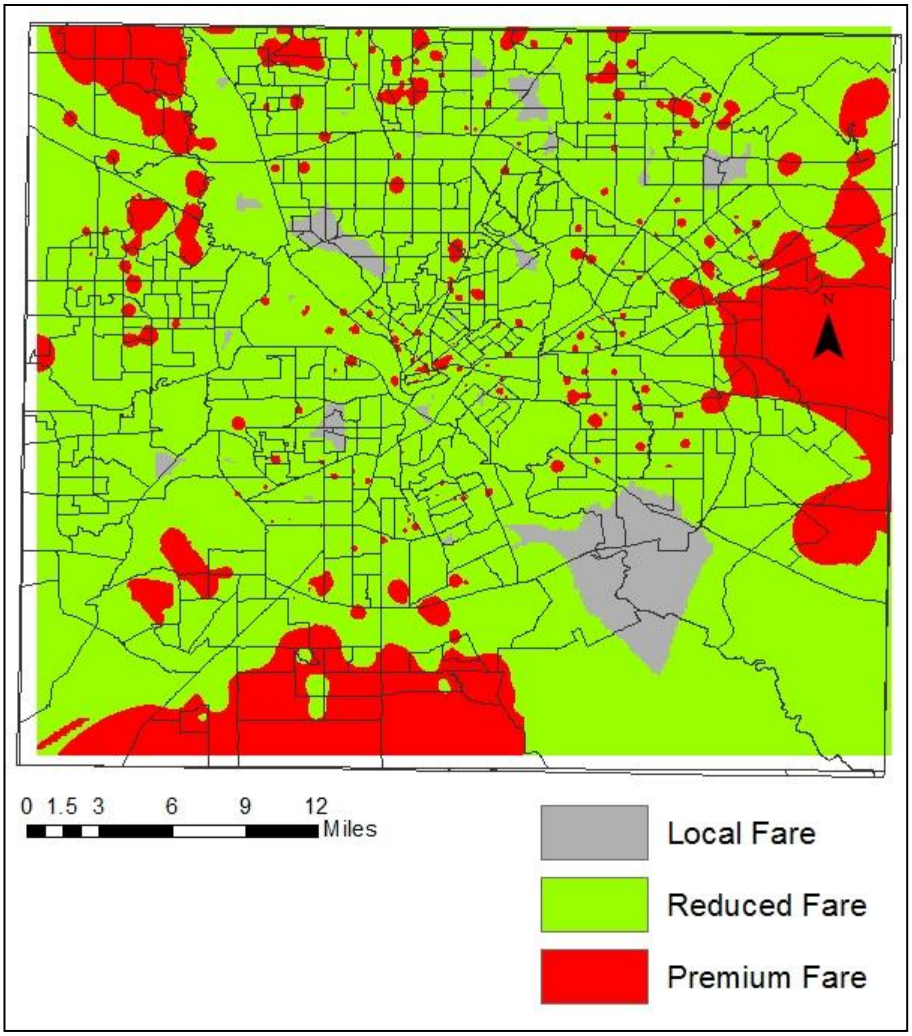

Figure 50 IDW interpolated map showing fare types paid by the workers for transit trips

Figure 50 shows that majority of the transit riders avail reduced fares, However transit users from some areas along the edges of the county seem to pay premium fares as well.

9.2 Statistical analysis

DART data was joined to the LUM, JHR and HAI variables that we had already computed in GIS, for the Dallas County. The attribute table was exported as a dbf.file, which was opened in SPSS for statistical Analysis. Relationships between the different variables of interest were computed using ANOVA.

9.2.1 Relationship between land use mix and trip distance

Trip Distance variable has been categorized from a range of 1-5, whereby 1.00 = <2 miles, 2.00 = 2 to 5 miles, 3.00 = 5 to 10 miles, 4.00 = 10 to 20 miles and 5.00 = >20 miles. As mentioned earlier, the land use mix entropy scores range from '0' (homogeneity of land uses) to '1' (heterogeneity of land uses). Results in the form of Descriptives for ANOVA are shown in Table 22. The outcome provides mean entropy score for LUM for each sub-category of trip distance, as well as the mean time for the whole sample i.e. total for all the census tracts of Dallas County. There is a statistically significant difference among groups when analyzed by one-way ANOVA ($F(4,3386) = 5.15$, p = .000). The mean entropy scores for LUM decrease with the increase in trip distance, indicating an inverse statistically significant relation between the two variables (Refer to the graph in figure 51). Hence it is proved that even the transit trip distances increase with the decrease in the mixing of land uses.

Table 22 Descriptives of one way ANOVA for LUM and trip distance

	Trip Distance (miles)	N	Mean for entropy score of LUM	S.D	S.E	95% C.I for Mean	
						L.B	U.B
1	< 2	163	.7032	.24992	.01958	.6645	.7418
2	2 to 5	667	.6467	.26240	.01016	.6268	.6667
3	5 to 10	1112	.6370	.26250	.00787	.6216	.6525
4	10 to 20	1222	.6223	.26119	.00747	.6077	.6370
5	>20	227	.5884	.29712	.01972	.5496	.6273
Total		3391	.6336	.26458	.00454	.6247	.6425
F-Statistic= 5.512, Significant at P = .000							

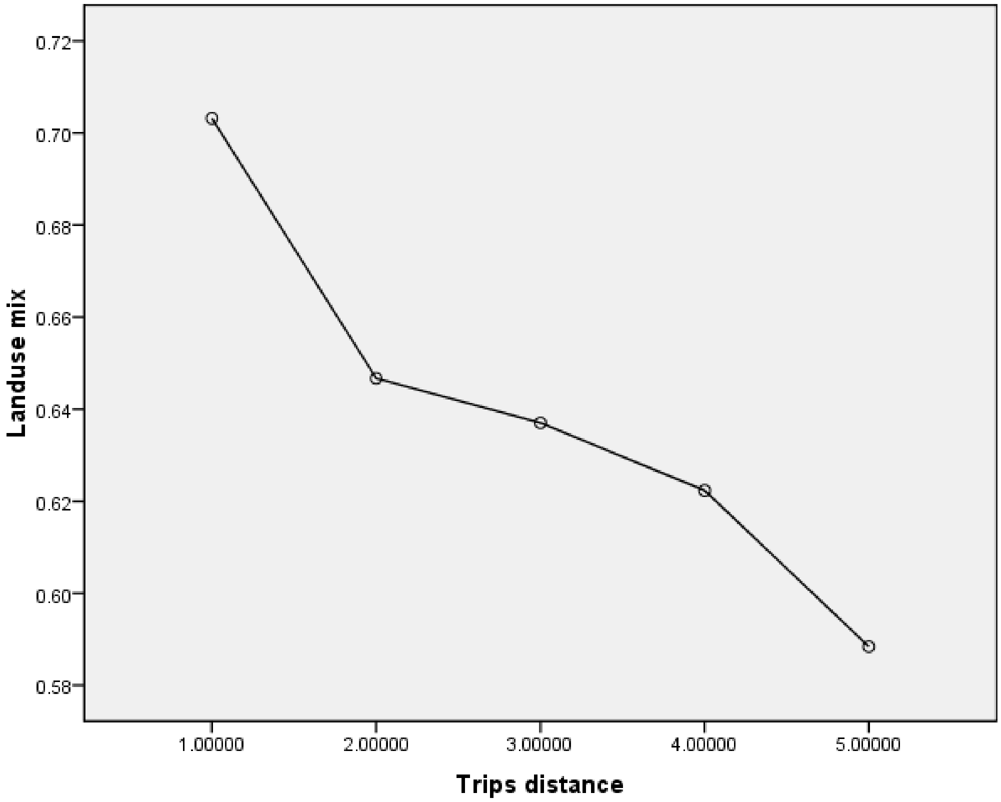

Figure 51 Graph showing the relationship between trip distance and entropy scores for LUM

Tukey's post-hoc test also revealed that the mean score for LUM was statistically significantly lower for longer commutes. The detailed on multiple comparisons for the same are shown in the Table 23.

Table 23 Tukey's Post hoc test (Multiple comparisons table) for LUM and trip distance

(I) tdist	(J) tdist	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	.05649	.02306	.103	-.0064	.1194
	3	.06616*	.02213	.024	.0058	.1266
	4	.08085*	.02200	.002	.0208	.1409
	5	.11478*	.02709	.000	.0408	.1887
2	1	-.05649	.02306	.103	-.1194	.0064
	3	.00967	.01292	.945	-.0256	.0449
	4	.02436	.01270	.308	-.0103	.0590
	5	.05829*	.02028	.033	.0029	.1136
3	1	-.06616*	.02213	.024	-.1266	-.0058
	2	-.00967	.01292	.945	-.0449	.0256
	4	.01469	.01094	.664	-.0152	.0445
	5	.04862	.01922	.084	-.0038	.1011
4	1	-.08085*	.02200	.002	-.1409	-.0208
	2	-.02436	.01270	.308	-.0590	.0103
	3	-.01469	.01094	.664	-.0445	.0152
	5	.03393	.01907	.386	-.0181	.0860
5	1	-.11478*	.02709	.000	-.1887	-.0408
	2	-.05829*	.02028	.033	-.1136	-.0029
	3	-.04862	.01922	.084	-.1011	.0038
	4	-.03393	.01907	.386	-.0860	.0181

*. The mean difference is significant at the 0.05 level.

9.2.2 Relationship between housing affordability index and trip distance

Results from one-way ANOVA indicate that the decrease in trip distance is associated with increased housing affordability Index for the area. Summary in the form of Descriptives for ANOVA are shown in Table 24. The outcome provides mean HAI for each sub- category of trip distance, as well as the mean time for the whole sample i.e. total for all the census tracts of Dallas County. There is a statistically significant difference among groups when analyzed by one-way ANOVA ($F(4,3386) = 15.346$, $p = .000$). The mean HAI decrease with the increase in trip distance, indicating an inverse statistically significant relation between the two variables. Hence it is proved that even the transit trip distances increase with the decrease in the overall housing affordability in the area (Refer to the graph in Figure 52).

Table 24 Descriptives for one way ANOVA for HAI and trip distance

Trip Distance	N	Mean for HAI	S.D	Std. Error	95% CI	
					L.B	U.B
< 2 miles	163	3.5933	2.01098	.15751	3.2823	3.9044
2 to 5 miles	667	3.3741	1.89924	.07354	3.2297	3.5185
5 to 10 miles	1112	3.0830	1.58087	.04741	2.9900	3.1760
10 to 20 miles	1222	2.9098	1.61166	.04610	2.8194	3.0003
>20 miles	227	2.6697	1.63143	.10828	2.4563	2.8831
Total	3391	3.0747	1.69862	.02917	3.0175	3.1319
F-Statistic=15.346, Significant at P = .000						

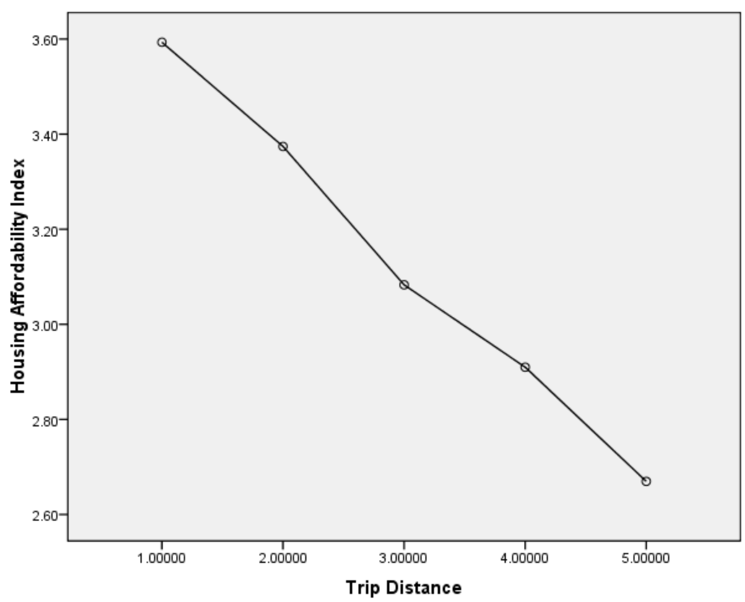

Figure 52 Graph showing the relationship between trip distance and HAI

Tukey's post-hoc test also revealed that the mean score for HAI is statistically significantly lower for longer commutes. The detailed multiple comparisons for the test are shown in the Table 25.

Table 25 Tukey's Post hoc test (Multiple comparisons table) for HAI and trip distance

(I) tdist	(J) tdist	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	.21919	.14717	.570	-.1825	.6209
	3	.51034*	.14127	.003	.1248	.8959
	4	.68348*	.14046	.000	.3001	1.0668
	5	.92362*	.17293	.000	.4516	1.3956
2	1	-.21919	.14717	.570	-.6209	.1825
	3	.29115*	.08249	.004	.0660	.5163
	4	.46429*	.08109	.000	.2430	.6856
	5	.70443*	.12943	.000	.3512	1.0577
3	1	-.51034*	.14127	.003	-.8959	-.1248
	2	-.29115*	.08249	.004	-.5163	-.0660
	4	.17315	.06981	.095	-.0174	.3637
	5	.41328*	.12268	.007	.0785	.7481
4	1	-.68348*	.14046	.000	-1.0668	-.3001
	2	-.46429*	.08109	.000	-.6856	-.2430
	3	-.17315	.06981	.095	-.3637	.0174
	5	.24014	.12174	.280	-.0921	.5724
5	1	-.92362*	.17293	.000	-1.3956	-.4516
	2	-.70443*	.12943	.000	-1.0577	-.3512
	3	-.41328*	.12268	.007	-.7481	-.0785
	4	-.24014	.12174	.280	-.5724	.0921

*. The mean difference is significant at the 0.05 level.

9.2.3 Relationship between job/housing ratio and trip distance

Results from one-way ANOVA did not indicate any definite pattern of association between in trip distance and JHR for the area. Summary in the form of Descriptives for ANOVA are shown in Table 26. The outcome provides mean JHR for each sub- category of trip distance, as well as the mean time for the whole sample i.e. total for all the census tracts of Dallas County. There is a statistically significant difference among groups when analyzed by one-way ANOVA ($F(4,3386) = 4.825$, $p = .001$).

Table 26 Descriptives for one way ANOVA for JHR and trip distance

Trip Distance	N	Mean JHR	Std. Dev.	Std. Error	95% CI	
					L.B	U.B
< 2 miles	163	1.1355125	.27615943	.02163048	1.0927984	1.1782265
2 to 5 miles	667	1.1504864	.31380245	.01215048	1.1266286	1.1743443
5 to 10 miles	1112	1.1141305	.30641429	.00918875	1.0961012	1.1321598
10 to 20 miles	1222	1.1578010	.30412494	.00869994	1.1407325	1.1748695
>20 miles	227	1.0858722	.33009770	.02190935	1.0426994	1.1290449
Total	3391	1.1361551	.30801977	.00528950	1.1257842	1.1465260
F-Statistic= 4.825, Significant at P = .001						

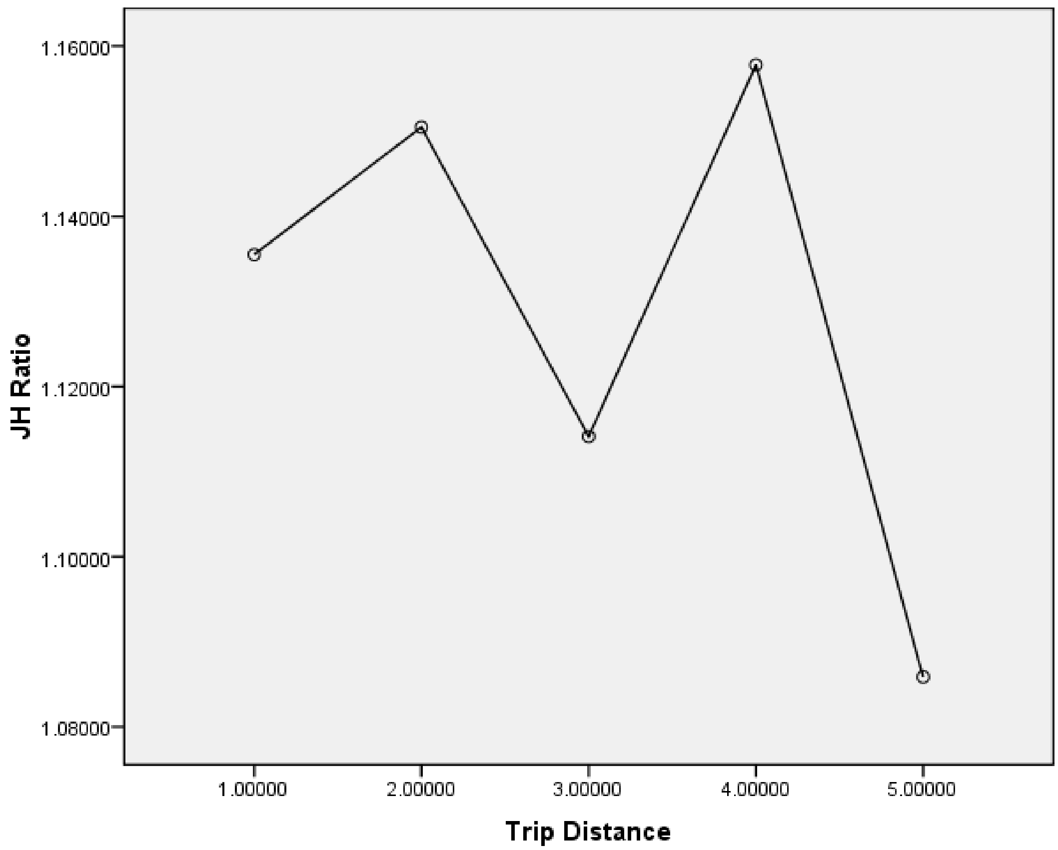

Figure 53 Graph showing the relationship between JHR and trip distance

Figure 53 shows the results of Tukey's post-hoc test and confirms that the mean score for JHR does not reveal a clear trend between the two variables. The detailed multiple comparisons for the test are shown in the Table 27.

Table 27 Tukey's Post hoc test (Multiple comparisons table) for JHR and trip distance

(I) tdist	(J) tdist	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-.01497399	.02685239	.981	-.0882608	.0583128
	3	.02138194	.02577565	.922	-.0489661	.0917300
	4	-.02228855	.02562691	.908	-.0922307	.0476536
	5	.04964030	.03155195	.515	-.0364727	.1357533
2	1	.01497399	.02685239	.981	-.0583128	.0882608
	3	.03635593	.01505128	.111	-.0047227	.0774346
	4	-.00731456	.01479511	.988	-.0476940	.0330649
	5	.06461429*	.02361531	.049	.0001623	.1290663
3	1	-.02138194	.02577565	.922	-.0917300	.0489661
	2	-.03635593	.01505128	.111	-.0774346	.0047227
	4	-.04367049*	.01273688	.006	-.0784326	-.0089084
	5	.02825835	.02238338	.714	-.0328314	.0893481
4	1	.02228855	.02562691	.908	-.0476536	.0922307
	2	.00731456	.01479511	.988	-.0330649	.0476940
	3	.04367049*	.01273688	.006	.0089084	.0784326
	5	.07192885*	.02221193	.011	.0113070	.1325507
5	1	-.04964030	.03155195	.515	-.1357533	.0364727
	2	-.06461429*	.02361531	.049	-.1290663	-.0001623
	3	-.02825835	.02238338	.714	-.0893481	.0328314
	4	-.07192885*	.02221193	.011	-.1325507	-.0113070

*. The mean difference is significant at the 0.05 level.

10. HOT SPOT ANALYSIS

The trends in the previous maps are somewhat subjective, i.e. the patterns are not that apparent to give as a clear picture of the areas the policy makers should target immediately to bring about a spatial match between workers jobs and residences and furthermore encourage land use mixing in those areas. In this section, we will investigate that the clusters seen in the previous maps are statistically significant and therefore worth investigating further. To achieve this it is appropriate to conduct Hot Spot Analysis in GIS. The tool is found in the spatial analyst tools in the mapping clusters toolset. Hot spot analysis gives us two new columns of values for each census tract -the Z-score and the P-value. We get high value Z-scores for hot spots and high negative value Z-scores for cold spots. P-value is the probability that the hot spot and the cold spot or the observed spatial pattern is just random, i.e. when the P-value is less than 0.1 that means that there is only 1 percent chance that the clustering occurred just randomly. This makes it a statistically significant hot spot. Hot spots are statistically significant clusters of high value and cold spots are statistically significant clusters of low value. The areas in red give the hot spots and areas in blue give the cold spots. The higher the Z-score values the stronger the color of the hotspots. Initially hotspots were calculated for the Dallas county LUM and HAI. Then the same analysis was run for MTT using US Census data for all trips.

In order to really understand if there are areas seriously under the homogeneity of land use problem we have used the above mentioned tool, which uses the Getis-Ord Gi* method. The map in Figure 54 shows the results of the analysis. The spatial picture concludes that there are statistically significant hot spots/cold stops of land use entropy mix in Dallas County. The cold spots are the north-eastern & Southern parts of county (i.e. low on entropy index for land use mix) and the hot spots are shown in red that are the areas under heterogeneity of uses. The cold spots thus give us the action areas where land use mixing is statistically significantly lower, and are under the greatest need of mixed land use policy reforms.

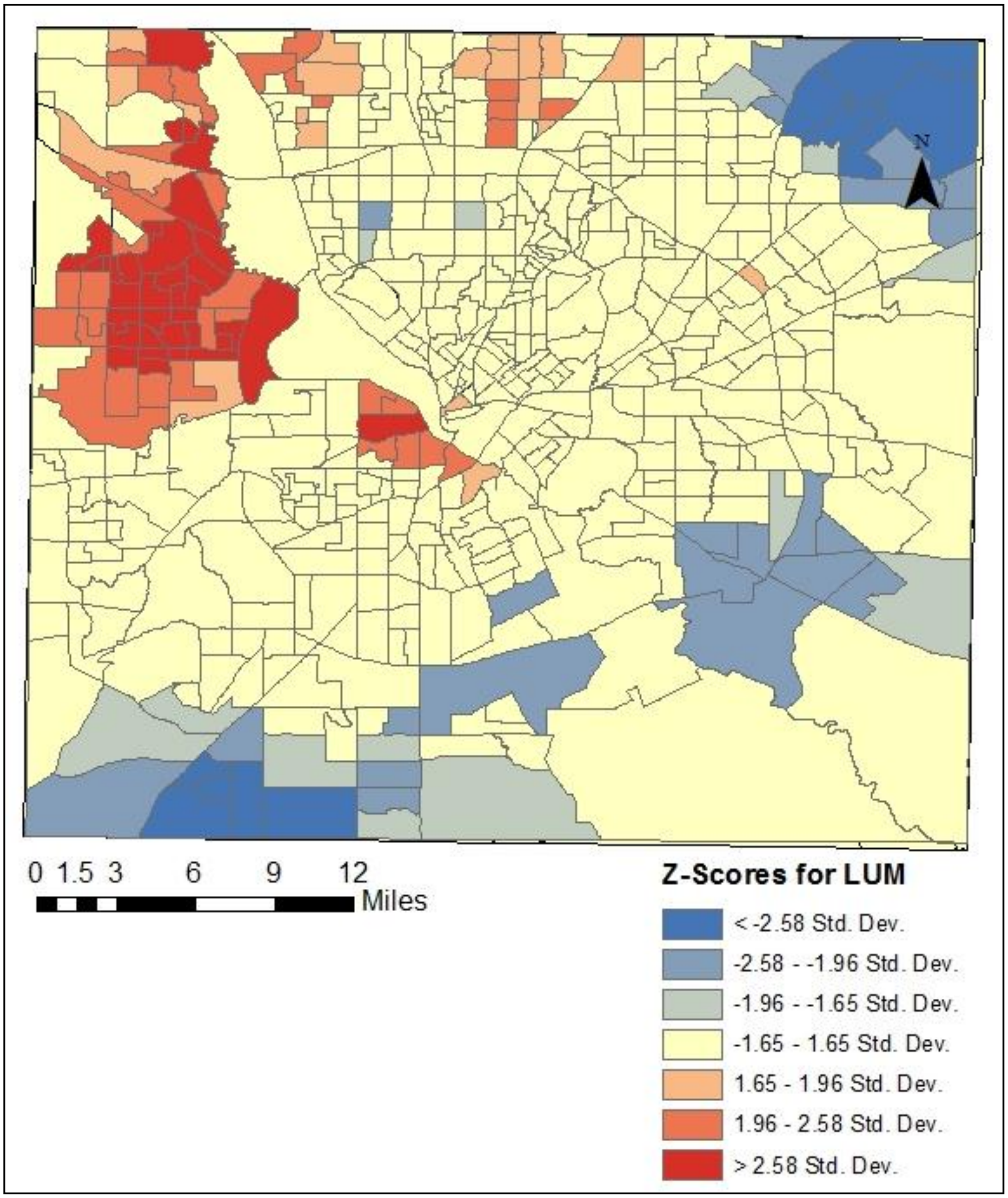

Figure 54 Hot spot analysis for LUM

Similarly hot spot analysis was conducted for housing affordability index (Refer to Figure 55). The map below shows the hot spots with greater housing affordability and cold-spots showing statistically significant spatial clusters where housing is not in the reach of the pocket of the workers. Again the trends show that north eastern and southern parts of the county are in need of provision of affordable housing.

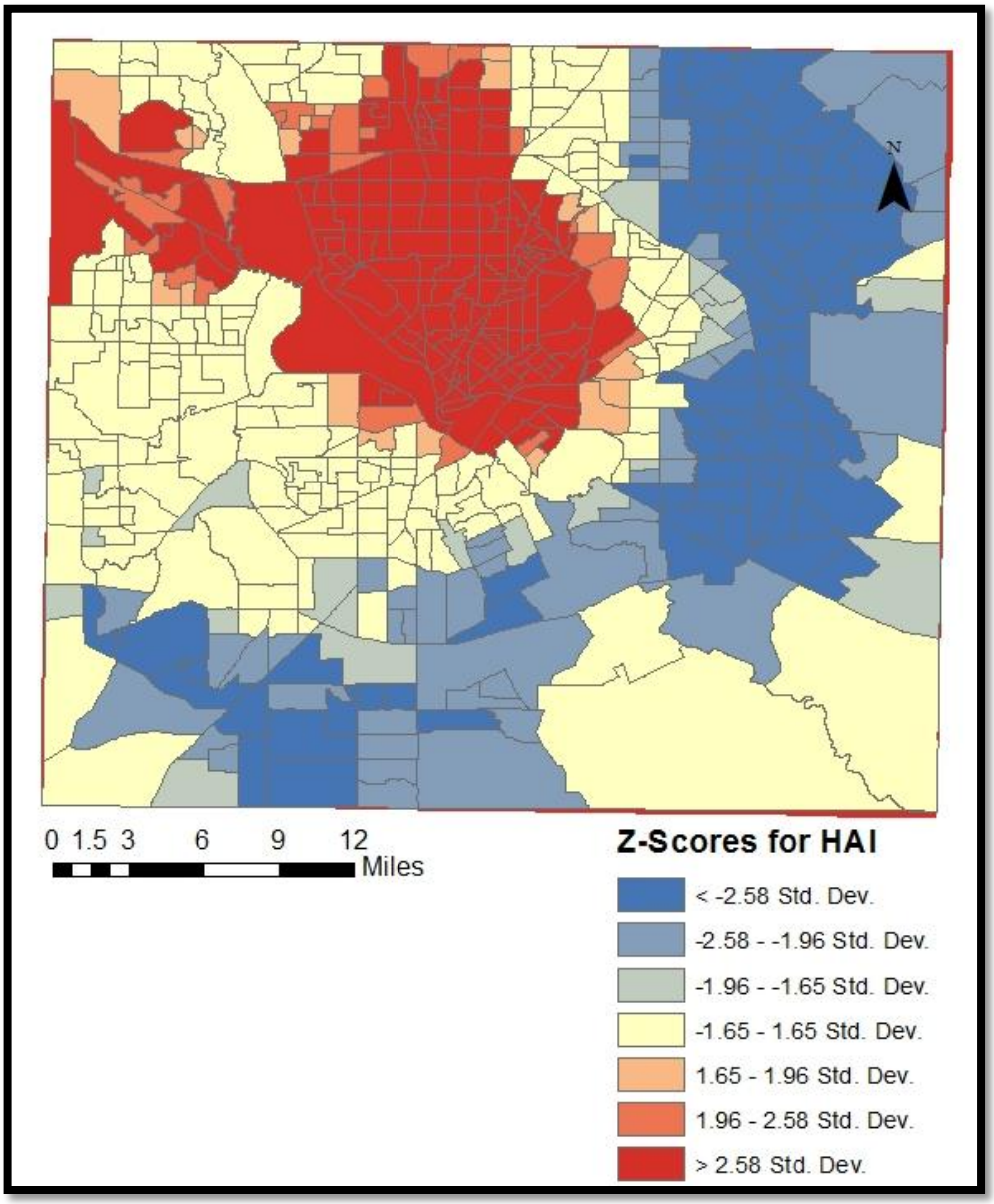

Figure 55 Hot spot analysis for HAI

10.1. Hot spot analysis for MTT to work (All trips)

The mean travel time to work is higher in area of hot spots marked in red clusters and it is less for cold spots in blue color in the north western quart of the county.(See Figure 56).

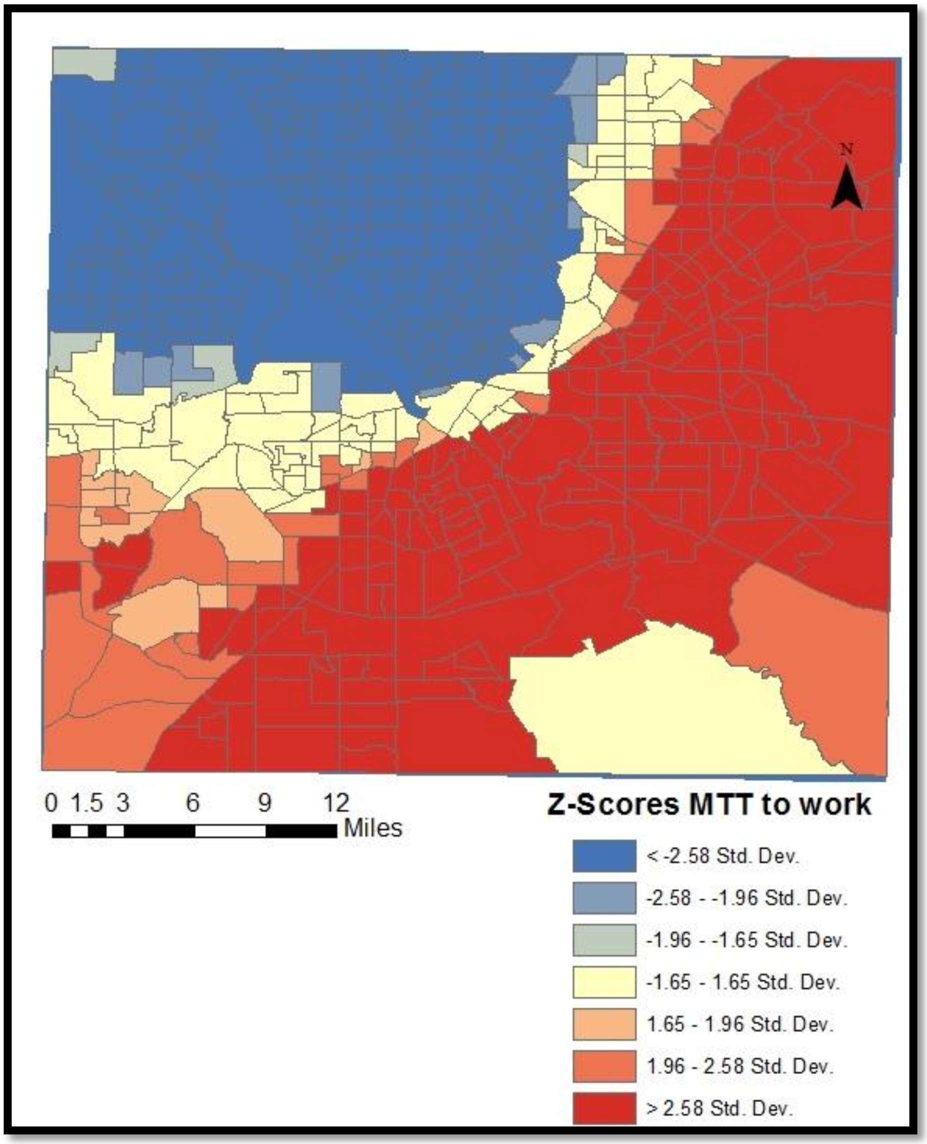

Figure 56 Hot spot analysis for MTT to work (All trips)

10.2 Hot spot analysis for MTT to work (Transit trips)

The same analysis was used on the Dallas Area Rapid Transit data to check the hot and cold spots with the travel distance and travel time variable. As the transit Data is in the form of points/events shape file, the hot spot analysis was conducted on the Transit Data points and then IDW Interpolated maps (Refer to Figures 57 and 58) were generated from these points to give us a spatial picture of statistically significant hot spots and cold spots. Trip Distance v/s trip time for transit trips was checked by applying the above technique on trip distance and trip time variables.

Hot Spots for trip distance show blue spots in the centre indicating statistically significant clusters of areas where distances to work are relatively lower and the red spots in the south have workers with longer commutes. As for the MTT by Transit, the central circle has the least travel times to work and red areas are statistically significant clusters for longer commuting time to work.

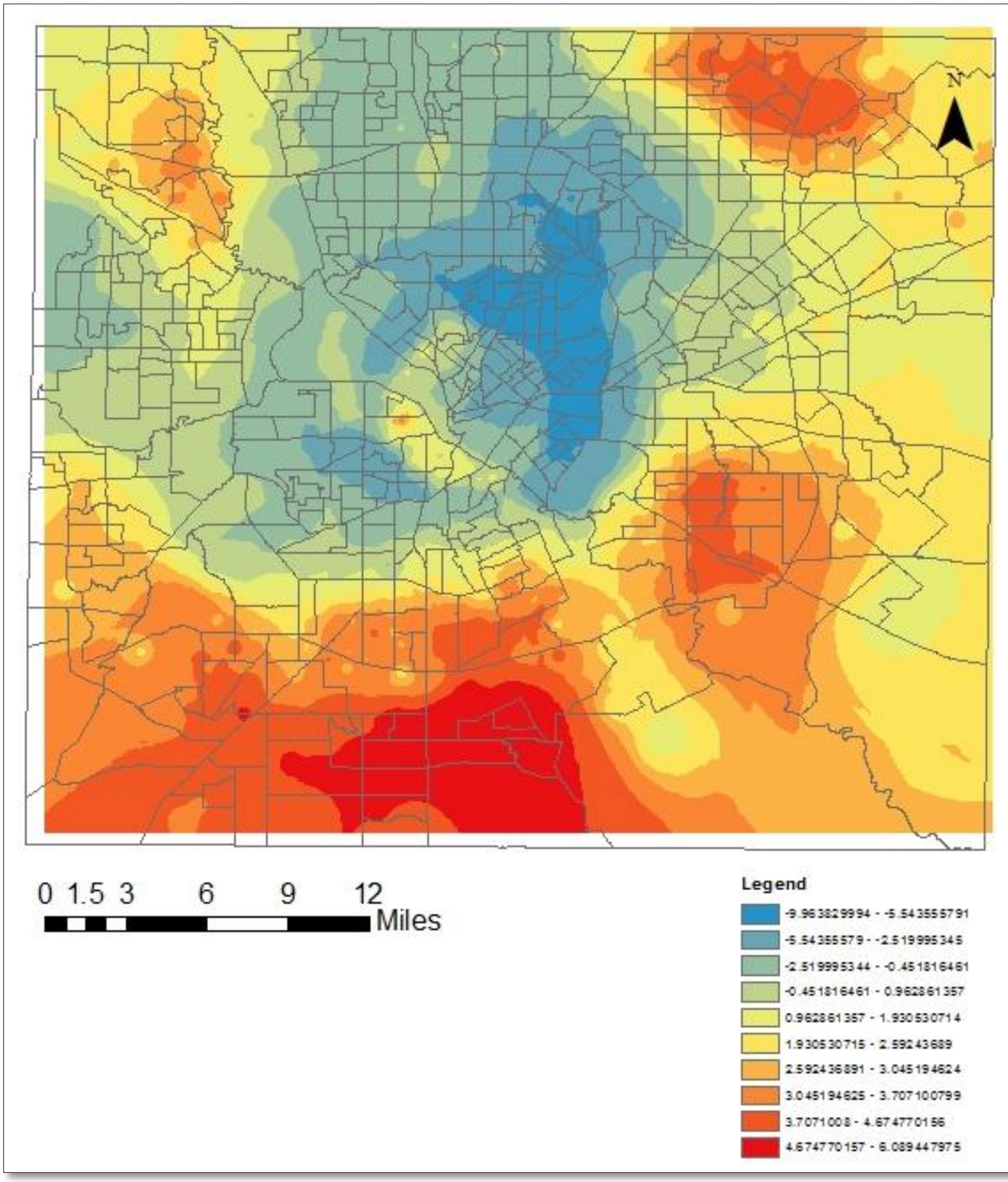

Figure 57 Hot spot analysis for trip distance (Transit trips)

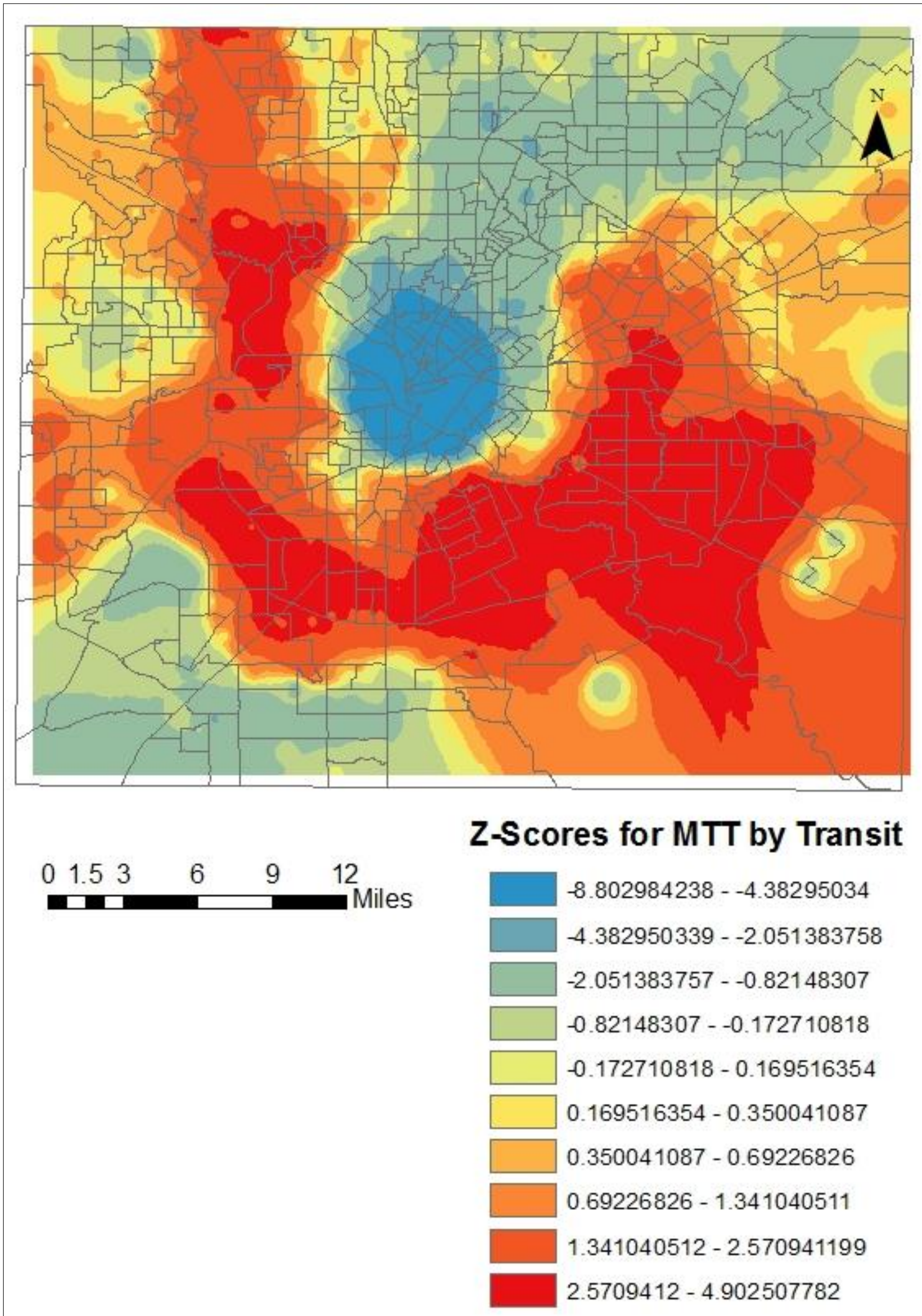

Figure 58 Hot spot analysis for MTT by transit

11. RESEARCH FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This section brings out the findings of the research in condensed form and gives the course of action/recommendation to resolve the issues identified.

11.1 Summary of research findings

The study provides an innovative technique to investigate the relation between J/H balance, LUM and commute to work. The goal is to reinforce sustainable development by attempting to curb commuters time and distance. It uses GIS and statistical capabilities of SPSS jointly to produce a clear understanding of most critical issues in the field of land use transportation interaction. However, the synthesized results below give us the analyzed information in condensed form:

11.1.1 Summary of the LHED, LED, QWI analysis

All the six types of analysis conducted with the selected data indicate a clear picture of mismatch between jobs and residences. The north and north-eastern Dallas area are found to be really attractive places to reside for most of the workers and for the young adults the downtown and uptown Dallas area is considered magnetic, the families with children mostly focus towards the north-eastern side of the county including cities like Garland, Richardson, Rowlett and Mesquite. Employment is mostly concentrated in the north and north western parts of the county including Irving, Addison, and Farmers Branch, University Park / Highland Park etc. Moreover, Desoto in the south is also a job attraction.

As far as travel characteristics are concerned, more than 55% of workers travel greater than 10 miles and 18% even travel greater than 25 miles to reach their workplace in Dallas County. For work census block to home census block, the longest commutes are towards the western and southern side of the county and the shortest ones are found along every direction but mostly concentrated along the north and north eastern quarter of the county. For home census block to work census block, the longest commutes are the same as from work to home i.e. towards the western and southern side of the county but the shortest ones are mostly concentrated along the north and north western quarter of the county. Thus we can conclude that the work trips are longest for the incoming and outgoing workers commuting in the county as well as for the south-western quart of the county, and trips are shorter in the north eastern side for the non-resident workers and north western quart for the resident workers of the county.

Furthermore, the research concludes that north western side of the county is Job rich, additionally many workers residing in the Dallas County, go to the bordering cities on the west, far north Dallas, outside the jurisdiction of county to work. Conversely, many workers of the Dallas County reside in the Plano-McKinney area in the north, Heath area on the eastern side and Seagoville-Crandall area of Kaufmann County on the south-eastern side. As of Inflow/outflow analysis there are 718,934 non-resident workers employed in Dallas county and 292,872 workers reside in Dallas although employed outside the county. A total of 621,302 are resident workers. Thus Dallas County acts primarily as a labor force hub and secondary as a labor force provider.

The analysis clearly indicates a lot of inter-county activity taking place. As was expected, the inflow of workers is much greater than the outflow of workers owing to a greater number of employment opportunities in Dallas, as compared to the surrounding counties. However the greatest inflow is from the Tarrant County, followed by Denton and Collin County respectively. The same county order follows when the outflow was investigated but definitely with fewer workers leaving Dallas and going to other counties for work. It is interesting to note that 216,514 trips have been made from places beyond the surrounding counties to the Dallas County and 104,139 trips have been made from the Dallas county to places beyond the adjacent counties. This reveals the extent of extra mileage travelled by people to reach their employment places. The analysis of LHED, LED and QWI data has given us a detailed picture of J/H mismatch and accordingly helped us understand the complexities related to residential preferences and access to work.

11.1.2 Summary of the JHR analysis

JHR map gives us a spatial picture of Very Housing Rich (JH ratio less than 0.85), Housing Rich (JH ratio >0.85 but less than 1.2), Balanced (JH ratio>1.2 but less than 1.7) and Job Rich Areas (JH ratio>1.71).Results in the form of Descriptives for ANOVA provides mean time to work for each sub-category of J/H ratio as well as the mean time for the whole sample i.e. total for all the census tracts of Dallas County. There is a statistically significant difference among groups when analyzed by one-way ANOVA (F (3,522) = 3.726, p = .011). Tukey's post-hoc test also revealed that the commute time to work was statistically significantly higher for Very Job housing rich (27.36± 6.65 min, P = .007) when compared to Housing rich areas (24.5 ± 5.80 min, P = .007). However, there were no statistically significant differences between the rest of the groups including JH balanced areas (25.49 ± 4.1 min) and Job Rich areas 25.90 ± 6.24 min). Curve analysis information further identified that the relationship between MTT and JHR is not linear but quadratic because MTT is high when the JHR gets severely imbalanced i.e. less than 0.8 and greater than 1.7.

Furthermore HAI was calculated and the HAI map shows areas under greatest stress of housing unaffordabilty. The SPSS results indicate that there is a statistically significant difference among groups (HAI balanced and Imbalanced) when analyzed by one-way ANOVA (F(2,526) = 48.087, p = .011). The Mean Travel time for HAI balanced areas is significantly lower than HAI imbalanced areas. Giving another proof of Job Housing match as an efficient strategy to reduce wasteful commute.

11.1.3 Summary of the MLR

The results of best MLR model suggest that the socioeconomic and travel characteristics of workers together with J/H ratio, HAI and land use mix, explain about 62% variation in "Commute time to work" ceteris peribus other explanatory variables. The usefulness and validity of the model was confirmed by F-Statistic 38.230, which was found to be significant at P-value of 0.001. The explanatory variables such as white workers, walk as travel mode to work, workers having education level of bachelors and above, and HAI were found to be statistically significant predictors of the dependent variable and have an inverse relation with MTT. However, Black workers, public transit as travel mode to work, household size, male worker and median age have direct significant relation with MTT. These findings led to the authentication of our research hypothesis that land use mix, J/H ratio and HAI are all statistically significant predictors of commute time to work.

The coefficients of explanatory variables conclude that more white people are associated with shorter commute times and more black people are associated with longer commute times. Additionally, workers using public transit as mode of travel to work, are associated with longer commute times likewise those who walk to and from their work place , are associated with shorter commute times. Workers having education level bachelors and above are associated with shorter commute times. For every one unit increase in median age the mean commute time to work increases by .103 units. Similarly one unit increase in the household size is associated with 1.880 unit increase in the mean commute time to work. Besides this male workers have slightly longer commute times than the female workers. All the above mentioned is true ceteris paribus the other explanatory variables.

Moreover, we can confirm that J/H is a significant predicator of mean commute time to work and ANOVA results indicate that MTT to work is less for J/H balanced areas. Greater housing affordability Index is associated with shorter commute times, indicating that those census tracts which offer greater housing affordability have a smaller mean commute time to work. Finally we come to the chief interpretation our research, which says that the greater Land use mixing is associated with shorter commutes. As we know that a “0" for LUM, represents homogeneity i.e. all uses are of single type e.g. commercial and "1" represents heterogeneity of land uses, thus regression results indicate that one unit increase in the LUM is associated with a 1.904 units decrease in the Mean time to work, holding other things constant.

11.1.4 Summary of target area analysis

Overlay Analysis performed in GIS gives a spatial picture of census tracts under greatest stress of J/H mismatch, low housing affordability and least mixing up of land uses. Results show that Irving, Coppell, Carrollton, Richardson and North west Dallas city area are found to be low priority areas (under less stress score), as they are already doing well on the scales of measures adopted for this analysis. However, cities like Grand prairie, Hutchins, Desoto, Cedar hill, Mesquite, Garland, Rowlett, Seagoville, Lancaster and Glen Heights are in a greater need of land use reforms.

11.1.5 Summary DART data analysis

GIS analysis gives us the IDW interpolated maps for different variables of DART ridership data. The generated maps give a spatial picture of trips distance, trip times, number of transfers made, household income map of the riders etc. The variables are then joined with the land use variables (JHR, HAI, LUM) and statistically analyzed. As identified in the earlier sections of this research that increased entropy scores for LUM and HAI are associated with reduced travel times, analysis of variance using DART ridership data confirms that the same is true for the transit riders as well. However the results did not find a clear relationship between JHR and travel time/ distance to work for transit riders.

11.2 Conclusions and recommendations

The research findings provide valuable understanding for policy makers geared to achieve sustainable land use and urban growth. The Analysis of Variance tests, Multiple Linear Regression and cartographic evidence, all support the research hypothesis that a statistically significant relationship exists between the imbalance of jobs to housing (J/H), Land use mix and mean travel time to work i.e. with the increase in the mixing of land uses and J/H balance MMT decreases, controlling for the other variables. Hence the policy makers and related professionals should take necessary measures for the achievement of optimal J/H ratio. As such, the results call for a twofold approach to deal with the Job-Housing imbalance in Dallas County. The goal is to bring about jobs in the housing rich areas and likewise to supply affordable housing in the Job-rich areas.

At a broader level, J/H balance should not be considered as a policy rather it should be considered an indicator. It should be made a goal by using different supportive/ complimentary strategies to attain the most balanced environment. Zoning revisions need to be carried out to get rid of rigid single use zoning and mixed use should be promoted by complimentary strategies like Transit-oriented development (infill and contagious development), Brownfields redevelopment, Neo urbanism etc. Congestion pricing and parking regulations should also be considered as supporting transportation policies. Moreover, it should also be kept in mind that job-housing match is often a derivative of complimentary landuse-transportation strategies like congestion pricing, parking regulations, smart growth etc, so importance must be given to such policies rather than dealing solely with the attainment of getting the right J/H balance intentionally.

As mentioned earlier that findings of this research support the aims of promoting mixed land use and J/H balance in the neighborhoods. Though urban and regional planners and policy makers have been concentrating more on the mixing up of land uses but they have been ignoring job and residence parity. These policies go hand in hand. The need is to adequately address and act on these policies aggressively. Urban Planners are often stuck between the choices of whether to add new employment centre or new housing development. This research helps them to spatially identify the areas under greatest stress/ need of these reforms and target them accordingly. In the case of Dallas County these were mostly multifamily living in the southern side of the county with more black population. The analytical model developed can be exercised as a strategic tool to tame land use growth and related decisions aimed to strengthen jobs-housing balance, which will ultimately improve the quality of life, congestion & air pollution levels, conserve fossil fuel by reducing VMT, lessen the charges on businesses & commuters, decrease public spending on facilities & services, enhance family stability and allied negative externalities.

At the general level efforts should be made from all the sections of the society to help promote reduction in the auto use. However, this research concentrates on reducing the trip distance rather than reducing the overall trips, bringing origins/destinations closer to each other because everyone living far away from their work place is contributing to traffic congestion and air pollution. The allied benefits include provision of affordable housing, time saving, environmental, curbing sprawl, conservation of fossil fuel, community development, greater efficiency in the use and provision of transportation infrastructure and services. Moreover, specific actions are needed from many professionals to achieve these goals. The key is to gather the potential allies of these policies , i.e. to co-ordinate the proponents of social equity, pedestrianization, biking etc. Additionally we need to co-ordinate all the stakeholders/ proponents of smart growth, transit oriented development, neo urbanism and bring them under one consensus i.e. to support LUM and J/H balance, the key actors and their role to achieve this is as following:

11.2.1 Role of urban and regional planner

This research provides a whole toolbox for Urban and Regional planners to assess the current urban land/built environment issues. The innovative techniques used to investigate these land use issues can bring very fruitful results to identify the problem areas. Once the professionals make the selection of action areas they can gear towards the preparation of policy measures to eradicate them. Planners' most prominent role is to strengthen the legal framework for local comprehensive plans and land use regulations promoting J/H balance and LUM. A planner should remove the impeding factors in the way to the success of these policies, where developer wants to provide low cost housing he is often stopped by exclusionary and rigid zoning. This calls for the revisions and modifications to the existing plans. It is important for planners to realize that land use mix is a regulatory tool and J/H balance is an indicator to the planning tools and they both work together to get the best results not only at regional level but also at the state/local level. They should promote policies like inclusionary housing5, linkage policy6, inter-regional partnership and Regional Housing Needs Determination7 (RHND) and many more. At the same time it should be kept in mind that urban containment strategies alone cannot revitalize the cities these must be supported by increased employment densities in the central city targeting the employment opportunities not just the people (Bright 2005).

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[5] Inclusionary zoning is very different from affordable zoning , it is primarily oriented towards private for-profit home builders. The policy functions through zoning mechanisms, whereby by the developers are forced by law to provide mixed-income housing development with a goal to minimize economic segregation Rusk, D. (2002). "Evaluating Inclusionary Zoning Policies." DRusk@ Starpower. Net **A project of the Wellesley Institute**.

6 A policy that requires employers to provide housing for the new work force

[7] The Government and related regulatory agencies must identify areas within the region sufficient to house an eight-year projection of the regional housing need. Additionally, the RHNA must allocate housing units within the region consistent with the development pattern included in the Sustainable Communities Strategy (SCS).Landis, J. D. (2004). "Ten steps to housing affordability in the East Bay and California." IURD Reprint Series, Institute of Urban and Regional Development, UC Berkeley **UC Berkeley: Institute of Urban and Regional Development.**(IURD Reprint Series).

Planning professionals should give incentives and incremental benefits to the developers in the form of grants, loans, tax increment financing etc to practice infill development. As an example, promoting infill housing in Job-rich areas is a very efficient strategy. This would accommodate the forecasted population, give employees the prospect to live closer to work, and possibly reduce inter and intra-county trips. Additionally, it would be imperative to build upon the tradeoffs between travel expenses and housing affordability. Planners should reevaluate the comprehensive plans, long term land use plans and the local regulations, with an aim to realign them with the J/H match and mixed land use rules. Planners should not let the market decide fate of cities, uptil now America has been at the hands of automobile supporters who do not care about of the regional implications of the same. This has resulted in incremental piece meal development with bedroom communities, edge cities and many more planning and societal issues. Finally at the grass root level, planners should encourage and create awareness among people about the benefits of living near their work place.

11.2.2 Role of elected officials

It is high time that the elected officials realize the substance of J/H balance and LUM in long-standing financial vitality. It is important to understand that the problem is both qualitative and quantitative. It is not that we need more housing or more jobs it is just the achievement of the right balance both in terms of number and type/quality. The condition, affordability and characteristics of housing should match the labor force. However, political strength of the affluent has always been a hurdle in the achievement of this objective with the major aim to maintain a class difference between socio-economic and ethnic groups. It is the duty of elected officials to educate themselves about these policies thoroughly and also to spread awareness about the importance of J/H balance and LUM in the general public. This will resolve the issues of public acceptability and conflicting demands against the regulatory framework proposed.

Furthermore strategies to enhance urban core by understanding and implementing the agglomeration economies through investing in physical and human infrastructure would also be a plus (Bright 2000).

11.2.3 Role of business owners

It is far more challenging to put in low income housing than to add low-paid jobs to a community. The employers will definitely find their target areas i.e. where the skilled labor lives. The business owners' interest comes in a different way in this scenario. LUM and J/H balance will minimize the workers time lost in wasteful commute, furthermore, workers will be saved from stress and frustrations associated with the long journeys to work. This saved time can be used positively by business owners and the affirmative effects on workers mental health will also add to the productivity of firms. In Pakistan mostly the leading educational institutes provide housing for their teachers, other administrative and supporting staff adjacent to the campus, so as to facilitate the students and teachers etc to have efficient access to each other and the campus itself. Similarly, the Business owners should make an effort to provide suitable housing to their team.

11.2.4 Role of land developers

Another point of concern and often a limitation to the Job/Housing match research is the big question of personnel choices/preferences i.e. Whether people do want to live closer to their work place or not? Or do they have other residential inclinations. They may be interested to live near better schools, better parks/open spaces or crime free/ safe areas etc. It is the most convoluting part, to get consensuses on what a society wants when it comes to housing choice. Nonetheless, it is still is significant to provide housing choices to a person who wants to live closer to their home in the form of affordable housing. History provides evidence to the fact that land developers are more interested in the provision of high end housing due to market forces and responsiveness of development this results in the dislocation of urban poor through gentrification and social stratification. As such, the role of land developers is to urge for a regulatory environment that encourages density bonuses, accessory units, Planned unit developments (PUD's), development impact fee waiver for mixed uses etc and make full use of these policies wherever they are all already in place.

11.2.5 Role of the economists

Economists mostly propagate the notion to let market decide the future of cities. They believe that the J/H balance is going to occur naturally so there is no need to take deliberate actions towards the policy by the government (Bookout 1990). As mentioned earlier adding low income housing to an area is far more difficult than adding low-paid jobs to a community i.e. the areas with deficiencies of jobs are often corrected naturally by the market demand but the solution is not vice versa. This calls for a dire need to understand the mechanics of J/H balance and LUM as a land use control and guiding measure. Economists should play a positive role in reshaping public finance policies that particularly influence land use mix and J/H balance in an area. They should focus finances, transportation and related infrastructure in the cores of cities to curb sprawl. Evidence shows that population and jobs both are significant to the health of the central city but employment intensification is more imperative of the two. Containment strategies can be more effective if they concentrate more on capturing jobs rather than residents (Bright 2005).

11.2.6 Role of the general public

Local planners should start campaigns to educate the community about the potential benefits of adequate land use policies for the region. All the citizens of US should realize that the total cost of wasteful commute will be borne not only at individual level but the whole society has to pay the price in terms of air pollution, burden on fossil fuel usage, road and related infrastructure etc.

11.3 Further research

Further research in the field should be geared towards incorporating personnel preferences/ choices of the workers while commuting to work and the factors responsible towards their housing choices. The big question is that whether people want to live in close proximity to their work place altogether or not? Or do they have other preferences?

Secondly in terms of LHED, LED and QWI data work trips should be analyzed by the category of Industry types/ field, so as to identify and segregate blue collar and white collar jobs in the area and accordingly provide the adequate housing type. This would also help create and achieve the right balance between jobs and houses.

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APPENDIX A

SURVEY INSTRUMENT FROM RIDERSHIP SURVEY BY NUSTATS

4. If you **TRANSFERRED** to get to **THIS BUS/TRAIN**, which bus/train **ROUTE** did you use? *(mark one only)*

- ○ I did not transfer
- ○ Bus Route Number/Name: ____________
- ○ Red Line (light rail) ○ Blue Line (light rail) ○ Trinity Railway Express

5. Including **THIS BUS/TRAIN**, how many **TOTAL** buses/trains will you ride to make **THIS ONE-WAY TRIP**?

- ○ 1, only this bus/train ○ 2 ○ 3 ○ 4 or more

6. If you will **TRANSFER FROM THIS BUS/TRAIN** to get to your **FINAL DESTINATION** which **ROUTE** will you use? *(mark one only)*

- ○ I will not transfer
- ○ Bus Route Number/Name: ____________
- ○ Red Line (light rail) ○ Blue Line (light rail) ○ Trinity Railway Express

7. How will you **GET FROM THE LAST BUS/TRAIN** to your **FINAL DESTINATION** on **THIS ONE-WAY TRIP**? *(mark one only)*

- ○ Walk: → *# blocks?* ○ Bicycle ○ Other (specify): ____________
- ○ Wheelchair: → *# blocks?* ○ Carpool (ride with someone else)
- ○ Get picked up ○ Drive alone

8. What type of place are you **GOING TO NOW**? (ending place of this one-way transit trip) *(mark one only)*

- ○ Work ○ Shopping ○ Restaurant
- ○ College/University *(student only)* ○ Social/Recreation ○ Other (specify): ____________
- ○ School (K-12) *(student only)* ○ Medical appointment/Hospital visit
- ○ Home → If you gave your Home address in Question 1 → **Go to Question 9a**

a. What is the name of the **PLACE, BUSINESS OR BUILDING** you are **GOING TO NOW**?

Place Name

b. What is the **ADDRESS** or **CROSS STREETS**?

Address

Cross Street

City Zip

9a. If you used/will use **RAIL** on this **ONE-WAY** trip, what was/will be the **FIRST** station and rail line where you boarded?
(If you transfer between lines, write where you boarded your first train.)

Rail Station

- ○ Red Line (light rail) ○ Did not/will not use rail on this one-way trip
- ○ Blue Line (light rail)
- ○ Trinity Railway Express

9b. If you used/will use **RAIL** on this **ONE-WAY** trip, what was/will be the **LAST** station and rail line where you will get off?
(If you transfer between lines, write where you will get off your last train.)

Rail Station

- ○ Red Line (light rail) ○ Did not/will not use rail on this one-way trip
- ○ Blue Line (light rail)
- ○ Trinity Railway Express

10. LIST ALL of the **BUS ROUTES AND RAIL LINES** in the **EXACT ORDER** you will use to make **THIS ONE-WAY TRIP:**

FIRST Bus Route or Rail Line:	➤	**SECOND** Bus Route or Rail Line:	➤	**THIRD** Bus Route or Rail Line:	➤	**FOURTH** Bus Route or Rail Line:

11. What was the **MAIN REASON** you took the routes in the order of the question above? *(mark one only)*

- ○ Shortest amount of time traveled ○ Fewest number of transfers ○ Only route(s) that I can get to
- ○ Shortest walking distance to and from route(s) ○ Ease of transfers ○ So I don't have to travel through certain neighborhoods
- ○ Least crowded route(s) ○ Only way I know ○ Other (specify): ____________

12. How many **MINUTES** do **YOU** think it will take to get from where you **STARTED THIS ONE-WAY TRIP** to where you will **END THIS ONE-WAY TRIP**?

 # Minutes:

13. HOW OFTEN do you make **THIS ONE-WAY TRIP**?

- ○ 1 day a week ○ 4 to 5 days a week ○ 1 to 3 days a month ○ First time riding
- ○ 2 to 3 days a week ○ 6 to 7 days a week ○ Less than once a month

14. Do you usually make **THIS ONE-WAY TRIP**...

- ○ Weekdays only ○ Weekends only ○ Weekdays and weekends

15. If **BUS/RAIL SERVICE** were **NOT AVAILABLE** how would you make **THIS ENTIRE ONE-WAY TRIP**?

- ○ Walk ○ Drive alone ○ Taxi
- ○ Wheelchair ○ Carpool (ride with someone else) ○ Would not make this trip
- ○ Get dropped off ○ Bicycle ○ Other (specify): ____________

16. How did you **PAY** for **THIS ONE-WAY TRIP**? *(mark one only)*

- ○ Cash (bus only) ○ Day Pass ○ Annual Pass
- ○ Single-ride Ticket (rail only) ○ Monthly Pass ○ Other (specify): ____________

17. Was your **FARE**...

- ○ Local ○ Reduced ○ Premium

18. How many registered **CARS, TRUCKS,** or **MOTORCYCLES** are available to your household?

- ○ None ○ 1 ○ 2 ○ 3 ○ 4 or more

19. Including yourself, how many **PEOPLE** live in your household?

- ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 or more

20. How many people **OVER THE AGE OF 15** live in your household?

- ○ None ○ 2 ○ 4 ○ 6 or more
- ○ 1 ○ 3 ○ 5

21. Are you...

- ○ Female ○ Male

22. What is your **AGE**?

- ○ 15 - 24 ○ 25 - 34 ○ 35 - 49 ○ 50 - 64 ○ 65 + years of age

23. Are you... *(mark the bubble that best describes you)*

- ○ Working full-time ○ Unemployed/Looking for a job ○ Student ○ Homemaker
- ○ Working part-time ○ Unemployed/NOT looking for a job ○ Retired

24. What is your **ETHNICITY**? *(mark the bubble that best describes you)*

- ○ Asian ○ Hispanic ○ White
- ○ Black/African American ○ Native American ○ Other (specify): ____________

25. What was your estimated combined **HOUSEHOLD INCOME** in 2006 before taxes?

- ○ Less than $10,000 ○ $15,000 - $24,999 ○ $35,000 - $49,999 ○ More than $75,000
- ○ $10,000 - $14,999 ○ $25,000 - $34,999 ○ $50,000 - $74,999

Please continue on the back →

APPENDIX B

CODING SCHEME FOR DART SURVEY INSTRUMENT

VARIABLE	CODESET
GCSTAT	HOD = Home, Origin, & Destination geocoded OD = Origin & Destination geocoded D1 = Walk >4 blocks D2 = Wheelchaired >4 blocks
TOD	1 = AM Peak 2 = Midday 3 = PM Peak 4 = Evening
DOW	1 = Weekday 2 = Saturday 3 = Sunday
LANG	1=English 2=Spanish
OPURP	1 = Work 2 = College, University (student only) 3 = School (K-12) (student only) 4 = Home 5 = Shopping 6 = Social/Recreation 7 = Medical appointment/Hospital visit 8 = Restaurant 97 = Other (specify): 99 = DK/RF
DPURP	1 = Work 2 = College, University (student only) 3 = School (K-12) (student only) 4 = Home 5 = Shopping 6 = Social/Recreation 7 = Medical appointment/Hospital visit 8 = Restaurant 97 = Other (specify): 99 = DK/RF

REASON	1 = Shortest amount of time traveled 2 = Shortest walking distance to and from route(s) 3 = Least crowded route(s) 4 = Fewest number of transfers 5 = Ease of transfers 6 = Only way I know 7 = Only route(s) that I can get to 8 = So I don't have to travel through certain neighborhoods 97 = Other (specify): 99 = DK/RF
MINUTES	open
OFTEN	1 = 1 day a week 2 = 2 to 3 days a week 3 = 4 to 5 days a week 4 = 6 to 7 days a week 5 = 1 to 3 days a month 6 = Less than once a month 7 = First time riding 99 = DK/RF
ONEWAY	1 = Weekdays only 2 = Weekends only 3 = Weekdays and weekends 99 = DK/RF
NOTAVAIL	1 = Walk 2 = Wheelchair 3 = Get dropped off 4 = Drive alone 5 = Carpool (ride with someone else) 6 = Bicycle 7 = Taxi 8 = Would not make this trip 97 = Other (specify): 99 = DK/RF
PAY	1 = Cash (bus only) 2 = Single-ride Ticket (rail only) 3 = Day Pass 4 = Monthly Pass 5 = Annual Pass 97 = Other (specify): 99 = DK/RF
FARE	1 = Local 2 = Reduced 3 = Premium

	99 = DK/RF
HHVEH	0 = None 1 = 1 2 = 2 3 = 3 4 = 4 or more 99 = DK/RF
HHSIZE	1 = 1 2 = 2 3 = 3 4 = 4 5 = 5 6 = 6 or more 99 = DK/RF
AGE15	0 = None 1 = 1 2 = 2 3 = 3 4 = 4 5 = 5 6 = 6 or more 99 = DK/RF
GEND	1 = Female 2 = Male 99 = DK/RF
AGE	1 = 15-24 2 = 25-34 3 = 35-49 4 = 50-64 5 = 65 + years of age 99 = DK/RF
EMPLOY	1 = Working full-time 2 = Working part-time 3 = Unemployed/Looking for a job 4 = Unemployed/NOT looking for a job 5 = Student 6 = Retired 7 = Homemaker 99 = DK/RF

ETHN1	1 = Asian 2 = Black/African-American 3 = Hispanic 4 = Native American 5 = White 10 = Two or more races 97 = Other 99 = DK/RF
INCOME	1 = Less than $10,000 2 = $10,000 - $14,999 3 = $15,000 - $24,999 4 = $25,000 - $34,999 5 = $35,000 - $49,999 6 = $50,000 - $74,999 7 = More than $75,000 99 = DK/RF
TDIST	1.00 = <2 miles 2.00 = 2 to 5 miles 3.00 = 5 to 10 miles 4.00 = 10 to 20 miles 5.00 = >20 miles
SEAT	1 = One-Seat Rider 3 = Three-Seat Rider 2 = Two-Seat Rider 4 = Four-Seat Rider
MMODE	1 = Bus Only 2 = Rail Only 3 = Bus and Rail