SPATIAL AND DWELLING DETERMINANTS OF ADULT ASTHMA EXACERBATIONS IN THE NORTH CENTRAL TEXAS REGION

by

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This work is dedicated to the loving memories of my parents: my father Muhammad Hanif and my mother Jahan Ara Begum

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Abstract

SPATIAL AND DWELLING DETERMINANTS OF ADULT ASTHMA EXACERBATIONS IN THE NORTH CENTRAL TEXAS REGION

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Asthma is an important public health concern as it is one of the major chronic diseases and is influenced by both environmental and genetic factors. The asthma situation is deteriorating in the North Central Texas. In such degrading condition of asthma, this research is one of the first attempts to investigate both indoor and outdoor environment quality and their relationships with adult asthma exacerbation i.e. adult asthma hospital admission rate in this region. To investigate this, I analyzed the geographical variation of about 12,000 adult patients hospitalized for asthma in the North Central Texas (NCT) Region and their association with the built environmental features such as land use types, dwelling characteristics, exposure to traffic at Census Block Group (CBG) level along with the concentration of pollutants at pertaining counties for the year 2014. Compared to previous studies, consideration of these factors can provide more location specific information. This is a key contribution of this research.

I have also investigated the social determinants of asthma at individual patient level as well as at CBG level. The results of my study indicate health discrepancy exists in this region since asthma hospitalization rate is significantly high (sig. <.10) in low income,

low education attained and black population prominent neighborhoods. In addition, females of black race are more vulnerable compared to male as well as than females of other races.

In case of outdoor built environmental variables, several land uses such as timberland, cemeteries and group quarters (nursing homes, college dormitories, etc.) have statistically significant and inverse relationship with adult asthma hospitalization. In case of transportation variables, the weighted averaged road density, weighted traffic speed, total travel time to work were considered as proxy to traffic exposure for the residents of each census block groups. Only “total travel time to work” was statistically significant and have negative relationship with adult asthma hospitalization indicating people who have severe asthma tried to avoid long commuting time. In case of indoor environmental quality, I considered different types of fuel used for house heating, absence of complete plumbing and kitchen facilities and dwelling structures older than 40 years were also considered to observe how these parameters of dwellings were influencing adult asthma condition.

I have also considered air pollutants (ozone, particulate matter 2.5 and pollen) at macro scale (i.e. at county level) due to availability of data at county level. To observe the combined relationship of significant indoor and outdoor variables at census block group level as well as pollutants at county level on the asthma exacerbation, I applied multilevel/ hierarchical linear modeling. This is another unique aspect of this research. Finally, I tried to provide some policy recommendations based on the major findings from my analysis.

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Glossary of Terms

Term	Definition
Asthma	Asthma is generally defined as a chronic disease that creates inflammation in the airways (respiratory tube/ bronchioles or bronchiole) that carry air in and out of the lungs (CDC.gov 2018).
Incomplete Kitchen facility	According to the American Community Survey (2015) and the U.S. Housing and Urban Development (2013), a complete kitchen must include a sink with piped water, stove/burner and a refrigerator. Absence of any of these elements would be considered as incomplete kitchen system.
Incomplete Plumbing Facility	A complete plumbing facility must include hot and cold running water, bathtub or shower and a flush toilet (American Community Survey, 2015). Absence of any of these elements would be considered as incomplete kitchen system.
Ozone (O3)	Ozone is not emitted directly into the air but is created by chemical reactions between oxides of nitrogen (NOx) and volatile organic compounds (VOC). This happens when pollutants emitted by cars, power plants, industrial boilers, refineries, chemical plants, and other sources chemically react in the presence of sunlight (The United States Enviironmental Protection Agency 2018)
Particulate Matter ($P.M._{2.5}$)	PM stands for particulate matter (also called particle pollution): the term for a mixture of solid particles and liquid droplets found in the air. $P.M._{2.5}$ is fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller (The United States Environmental Protection Agency 2018).
Multilevel models/hierarchical linear models (HLMs)	A type of statistical procedure belonging to the class of general linear models, adapted for analysis of clustered data(Dickinson, Miriam and Basu 2005).

Chapter 1 Introduction

1.1 Background

Epidemiologic, environmental science, as well as urban planning studies on geographic variation in asthma prevalence, have identified asthma as an important public health concern (Grant, Wagner, & Weiss, 1994; Hudak, 2014; Li & Newcomb, 2009). It is one of the major chronic diseases and is influenced by both environmental and genetic factors (Jie et al. 2013). According to the World Health Organization (2017), around 235 million people around the world are currently suffering from asthma and around more than 26 million people in the US are suffering from this disease (CDC.gov 2018; Asthma and Allergy Foundation of America 2018). In Texas, this number is about 15 million (CDC.gov 2018). Within Texas, the Dallas Fort Worth (DFW) Metro area is the worst place for having significant number of asthma patients and nationally it ranked 77th worst place for asthma prevalence (Asthma and Allergy Foundation of America, 2018). But in the year 2014, this region was the fourth worst metro area in Texas and 100th worst place in the nation (Asthma and Allergy Foundation of America 2014), this is indicating a deteriorating condition of asthma in DFW in recent years.

A growing body of literature on the possible contextual and geographic factors that are affecting asthma prevalence in North Central Texas have provided few ideas about the issue, such as traffic exposure and social inequalities of the neighborhoods with childhood asthma hospitalization (Li and Newcomb 2009), relationship between childhood asthma hospitalization rate and distance from major roads (Newcomb and Cyr 2012) have been studied by previous literature. A recent study by Newcomb P. and J. Li (2019) predicted social inequalities of adult asthma hospital admission as well as observed their association with traffic density and proximity to urban drilling sites. Though there are many other factors such as different land use, other traffic variables (traffic infrastructure, commuting time for adult), outdoor air pollutants as well as indoor environment quality and their relationships with adult asthma hospital admission are yet to explore. This is an important caveat. My research is an attempt to investigate this gap to portray the cumulative effect of both indoor and outdoor determinants on adult asthma exacerbation. In terms of exacerbation, I observed the adult asthma hospitalization rate in CBGs. This means, the condition of asthma patients was aggravated enough that they had to be hospitalized to get treatment for asthma.

In addition to the above-mentioned studies in DFW region, some researchers focused on condition of both adult and childhood asthma together. Those studies mostly focused on concentration of ground level ozone in DFW area and asthma severity such as whether advance ozone warning systems helped asthma patients to be prepared and were protective of acute asthma events (inpatient stays and emergency asthma visits) which was investigated by applying multiple lag model and found children are more susceptible to asthma than adults if bad ozone day alerts are ignored (Carls 2010). Other studies on similar aspects i.e. concentration ambient ozone concentration and pollen level found with Poisson regression analysis that, children with 5 to 15 years age are more prone to hospital visit than adult asthma patients during the month of August and September (start of a school year) (Goodman et al. 2017). Studies in north Texas region also considered concentration of ozone and asthma exacerbation for child and adult patients living in rural and urban counties but found no significant correlation (Khunsri 2015). All cases in DFW for adults which were considered along with childhood age groups were concerned mostly about ground level ozone concentration and found children were more vulnerable. The suspected reason behind this is the lower immune system of children and exposure to outdoor environment for the school going youngsters (Goodman et al. 2017; Khunsri 2015). But this does not indicate the condition of asthma is better for ozone or other pollutant exposure in adult age groups since the number of adult asthma patients are rising (Asthma and Allergy Foundation of America, 2018). This indicates, along with the consideration of ozone level, or other pollutant concentration, other factors may trigger adult asthmas which are needed to investigate for this metropolitan area.

Literature indicates that, there are different spatial factors that can have impact on asthma exacerbations. The spatial, urban and dwelling determinants that are related to asthma exacerbation were identified through literature review. Previous studies in other regions of the U.S. emphasized an association between asthma symptoms and exposure to air pollution (Ozone, NO2, PM2.5, SO2), as respiratory diseases among children and adult reported to be influenced by breathing polluted air (F. J. Kelly and Fussell 2011; Bruce et al. 2006; West et al. 2016). Depending on the spatial and temporal variation of pollutants as well as application of methods, the associations vary from weak to moderate relationship (Hudak 2014; Carls 2010; Gorai et al. 2015; Alhanti et al. 2016; Goodman et al. 2017; Khunsri 2015). Some studies particularly explored the impact of traffic exposure on asthma as it has been reported transportation is one of the major sources of air pollutants (EPA, 2000). Studies in other regions considered distance from major roads (Cai et al. 2017) as well as concentration of vehicular pollution (McConnell et al. 2010) to observe the impact on asthma patients and their results widely vary. As a measure of exposure to traffic, a European study considered commuting travel time for adults (Lindgren et al. 2010) as increased travel time reported to be influential for asthma exacerbation (Wright 2013).

Besides these, studies in other regions have emphasized on many other factors to investigate and explain the geographical variation of asthma patients. As a factor of geographical variability, several studies have considered to investigate land use categories and their influence on asthma. Studies found that, with the increase of green spaces asthma exacerbation decreases (Rao et al. 2017) and with the proximity to waste management sites asthma severity increases (Maantay 2001). Besides the outdoor environment, literature suggested indoor air qualities are also important to explore the variability of asthma exacerbation (Willers et al. 2006). For this, dwelling condition such as indoor air quality due to fuel used for house heating, condition of kitchen and plumbing were reported as potential contributors to adverse respiratory conditions (Belanger and Triche 2008; Casas et al. 2012; Moran et al. 1999; Ebisu et al. 2011; Mcdowell et al. 2016). Incomplete kitchen and plumbing, i.e. absence of any of the items such as stove/burner, refrigerator, sink with piped water, running hot and cold water, bathtub/ shower and flush toilet as defined by the American Community Survey and Housing and Urban Development, are reported to be associated with respiratory illnesses due to hygienic issues (Mckee-huger and Loosemore 2011).

In the case of north central Texas, there is little understanding about how traffic exposures, commuting patterns, land use factors, as well as dwelling condition that have impact on the adult asthma exacerbation or in other words adult asthma hospitalization rate. To investigate these gaps, this research considered the “Ecologic Theory” as the theoretical basis. This study analyzed the geographical variation of about 12,000 adult patients hospitalized for asthma in North Central Texas (NCT) Region and their association with the built environmental features such as land use types, dwelling characteristics, exposure to traffic at CBG level along with the concentration of pollutants at pertaining counties. Compared to previous studies, consideration of these factors can provide more location specific information. This is another key contribution of this research. Information of adult asthma patients are at individual level who are nested within contextual/aggregate units (at a higher level like census block groups or county). This research considered application of multi-level model to examine adult asthma exacerbation with respect to the surrounding built environmental features available at census block group (CBG) (unit of analysis) and county level. Previous studies on asthma prevalence and their relation with different geographic and environmental variables were conducted mostly by applying logistic regression methods like univariate (Ebell et al. 2017) and multivariate logistic regression models (Sternthal, Michelle J., Hee-Jin Jun, F. Earls 2010; Newcomb P. and J. Li 2019a; Ebisu et al. 2011; Mcdowell et al. 2016). Besides logistic regression models, researchers applied Nonparametric statistical (the Mann-Whitney U Test) analysis (Khunsri, 2015), Poisson regression (Alhanti et al. 2016) as well as chi-square statistics or Fisher exact test (McDowell et al. 2016; Newcomb and Cyr 2012). Studies observed the correlation among variables by applying Spearman rank (Khunsri 2015) or Pearson Correlation methods (Li and Newcomb, 2009). Consideration of data of different geographic levels and application of stepwise multilevel regression modeling after adjusting for factors such as age, race or income can make this study unique than previous efforts.

This study is one of the first attempts to investigate the geography of adult asthma in North Central Texas region. Moreover, this study is an endeavor to investigate both outdoor and indoor environmental factors that are reported by different literature as influential factors. The outcome of the research can help urban planners to plan or recommend for better urban areas by reducing the elements that influence asthma exacerbations. The takeaway of this research can be cautiously contemplated by public health researchers and practitioners that they can consider for remedial of asthma exacerbation. Policy makers and implementers can also understand the geographic as well as demographic factors behind asthma severity and hence can support the remedial efforts of relevant urban planning techniques. In this way, this research can contribute in the field of urban planning, public welfare and policies.

1.2 Purpose of the study

This study is an investigation about the condition of adult asthma in a previously understudied area with respect to traffic exposure, surrounding land use variation, dwelling condition, and commuting travel pattern. As this study considered the residential location of the adult asthma patients and surrounding built environment as well as quality of dwellings, the results can help planners and policy makers to plan for a healthy residential environment through reducing the externalities that exacerbate asthma or other breathing difficulties.

1.3 Research questions

It is hypothesized that, this research would help to explore the adult asthma hospital admission or asthma exacerbation condition in different Census Block Groups (CBGs) and their association with exposure to traffic variables, land use variations, and dwelling condition. This study would also help to reveal the social determinants of adult asthma in North Central Texas region. Besides this study would also observe the impact of air pollutant in different counties and a combined impact of all the variables on adult asthma exacerbation. Therefore, this research aims to address the following **research questions**:

1. Is there any relationship between proximity to major highways and adult asthma hospitalization rate at different CBGs (unit of analysis) of the NCT region?
2. Is there any relationship between the weighted density of different types of roads (arterial roads, distributor roads and local roads) and adult asthma hospitalization rate at CBGs of the NCT region?
3. Is there any relationship between weighted average speed of traffic and adult asthma hospitalization rate at different CBGs of the NCT region?

4. Is there any relationship between commuter travel time and adult asthma hospitalization rate at different CBGs of the NCT region?
5. Is there any relationship between different categories of land use and adult asthma hospitalization rate at different CBGs of the NCT region?
6. Is there any relationship between dwelling condition in terms of indoor air quality due to use of different types of house heating fuels and adult asthma hospitalization rate at different CBGs of the NCT region?
7. Is there any relationship between dwelling condition in terms of hygiene due to lack of complete kitchen and plumbing system with adult asthma hospitalization rate at different CBGs of the NCT region?
8. Is there any relationship between age of housing units and adult asthma hospitalization rate at different CBGs of NCT Region?
9. Is there any relationship between educational attainment, age, race, gender composition, economic status of CBGs and adult asthma hospitalization rate at CBGs located in the region?
10. Is there any relationship between ozone concentration (in terms of Eight Hours Ozone high value days) in counties and adult asthma hospitalization rate at CBGs located in pertinent counties of the NCT region?
11. Is there any relationship between PM 2.5 concentration (in terms of average daily density of fine particulate matter in micrograms per cubic meter) in counties and adult asthma hospitalization rate at CBGs located in pertinent counties of the NCT region?

1.4 Limitations of the study

Every research has limitations and this study is not an exception. One of the important limitations is data availability. Several epidemiologic studies have reported genetic condition, weight, smoking habit, and daily lifestyle, etc., are important parameters associated with asthma. However, data collected from the Dallas Fort Worth Hospital Council Foundation (DFWHCF), which collects data from hospitals across the north Texas region, does not include such detailed information. The DFWHCF data set do not have information of smoking habit, height, weight, asthma history data of asthma patients. The data policy does not allow disclosure of personal information and therefore there is no option to conduct a survey or focus group discussion on the adult asthma patients available from DFWHCF in order to investigate the asthma condition based on their living pattern and other genetic information.

Moreover, for indoor environment, studies considered different information they collected from survey responses. Different indoor environmental parameters can trigger asthma that can be unique to each person, it can include but not limited to tobacco smoke, pet, dander, dust mites, mold, etc. (Svendsen, et al. 2018). One of the datasets commonly used to measure the condition of dwelling in the United States is the US Census Bureau's American Housing Survey (AHS). The AHS collect detailed data on the quality of housing on a nationally representative sample of housing units. But the data do not have location specific information, therefore it was not possible to detect from which census block group a particular housing unit belong. Therefore, several factors such as information on vermin and use of cooking fuel were not able to include in the research. The US Census reports data on incomplete plumbing and incomplete kitchen facilities (Mckee-huger and Loosemore 2011) as well as house heating fuel and housing age. In this study, this data was used to explore the relationship of indoor environment with adult asthma exacerbation.

Moreover, this study cannot capture the detail biological factors or indoor environmental scenarios and results of the model may be influenced due to unavailability of these data. In addition, collection of data from different sources may also have an impact on the results.

1.5 Outline of the study

The research is divided mainly into ten chapters. The first chapter discusses the background of the study mentioning the theory from literature and important gap in the research. This section also discusses application of possible methods, purpose and questions of research and limitations of the study. Then the second chapter includes critical review of relevant literature in terms of the variables, methods, findings and limitations. The third chapter discusses research design mentioning data availability with the pertinent sources, data processing and methods. Chapter four includes detail discussion on overview of adult asthma patients, also focused on exploring about the group that are most distressed in terms of social elements. Chapter five discusses about detail land use categories mentioned by the North Central Texas Council of Government (NCTCOG), how those land use categories were influencing asthma exacerbation, spatial cluster analysis to visualize land use conditions in major hotspots of asthma exacerbations. Chapter six discusses about different variables of traffic exposures, how they were calculated as well as how they were influencing adult asthma situation in this region A spatial analysis for visual representation about major highways and location of hotspots are also discussed in this chapter. Chapter seven discusses about indoor environment quality parameters, such as house heating fuels, lack of plumbing and kitchen facilities and housing age were affecting adult asthma situation. Chapter eight discusses about different types of pollutants and their concentration at county level and provides a detail discussion about composite influence of built environmental variable located at CBG level and pollutant at county level on adult asthma hospitalization. Chapter nine discusses recommendation and implication of the study. Chapter ten concludes the study and discusses future research.

Chapter 2 Literature Review

2.1 Introduction

An extensive literature review was conducted to identify the research gaps discussed in previous chapter. Review of literature helped to determine the research objectives and develop a methodology to achieve those objectives. Besides discussing the general definition of asthma and related available policies in Texas, this chapter includes broad discussion about literature under different categories. As this study is focusing on north Central Texas or Dallas Fort Worth (DFW) region, related researches on asthma issues of DFW have been systematically reviewed. Besides, research from other regions were studied to know how public health (particularly asthma) is affected by surrounding environment that can be dealt with urban planning techniques. Such research explored outdoor environment such as exposure to air pollutants, transportation factors and surrounding land uses are related to asthma exacerbation. Moreover, studies have also focused on how indoor environment or the dwelling condition can affect asthma severity. This chapter provides an overview of relevant literature that offer understanding about the relevant factors, methods of analysis and findings regarding asthma severity under different environment condition and for different socio demographic characteristics.

2.2 Theoretical basis of the study

To understand and investigate health issues, researchers have conducted their researches under different theoretical approaches. Among different approaches, the “Ecologic theory” (also referred as the Socioecological theory) conceptualizes the dynamic interrelation among personal, social, physical environmental factors and health status (Bruhn and Galveston 1983; Richard, L., Gauvin, L., & Raine 2011). This theory was first developed as a conceptual model during 1970s and formalized as a theory in 1980 by an American psychologist Urie Bronfenbrenner. He introduced the theory to emphasize the importance of environment (or ecological system) in order to understand the development of children living in that environment (The Psychology Notes, n.d.; Bronfenbrenner 1979).

This theoretical approach has evolved and applied in many disciplines such as sociology, politics, economy, biology, education and so on. The contemporary developments of this approach have reinforced their relevance in the discipline of public health (Richard, L., Gauvin, L., & Raine 2011). The ecological way of thinking in public health was developed by number of primary contributors including Moos (2003); Stokols 1992); Barker, Roger G. (1949) and J. G. Kelly (1969) among others (Mclaren and Hawe 2005). They conceptualized and empirically tested the environmental influences on population health issues (Richard, L., Gauvin, L., & Raine 2011; Mclaren and Hawe 2005).

Regarding asthma, Bruhn and Galveston (1983) examined and discussed applicability of ten different theories in studies of self-management of childhood asthma. Among those ten different theories, Ecologic theory was one of them. According to him, one of the important aspects of this theoretical approach is that it accepts the continuous interaction and changing pattern of interaction among variables (personal, social, environmental variable and health status variables). The four basic components of this theory were outlined by (Kingry-Westergaard, Cynthia (1990): (a) it is a theory that explains both data and what is actually happening in terms of interrelationship between persons and environmental settings (built environment, social environment or other components of ecological system); (b) this theory provides social construction of ecological knowledge; (c) "collaborative style" and (d) "social processes" (mentioned by Richard et al, 2011).

This theoretical approach is a strong basis for my research that aims to investigate the relationship between adult asthma hospitalization (health issue) and surrounding environmental factors (built environment, dwelling condition and social environment).

2.3 Asthma: general definition and related health policies in Texas

Asthma is generally defined as a chronic disease that creates inflammation in the airways (respiratory tube/ bronchioles or bronchiole) that carry air in and out of the lungs. The inflammation makes the airways very sensitive and creates difficulty for breathing (CDC.gov 2018). Asthma symptoms may include wheezing, coughing, chest tightness and trouble breathing. In a severe asthma attack, the airways shrink so much that other body organs do not get enough oxygen. There is no cure for asthma. But with the proper diagnosis, medication and an asthma management plan, symptoms can be controlled (CDC.gov 2018).

In a report by the Environmental Protection Agency (EPA) (2014) after reviewing multiple lines of evidences it was suggested that while asthma is, to a degree, dependent on genetic factors, it is also affected by various environmental exposures (EPA 2014; Khunsri 2015). Indoor environment/air quality as well as outdoor environment/air quality have impact on asthma severity (Wieslander et al. 1997; Diette et al. 2007; Brugge et al. 2007). Asthma usually arises from an interaction between host and environmental factors. A rapid increase in asthma in recent years cannot be attributed to genetic factors only, but rather, to changes in environmental factors (Brugge et al. 2007; Jie et al. 2013). In addition to increased indoor air contaminant exposures, several outdoor environments as well as social factors that may contribute developing asthma morbidity have been studied. Among factors that have been given widespread attention are pollutant concentration, traffic exposure, geographical variations, socioeconomic status (SES), and ethnicity (Jie et al. 2013).

As mentioned earlier, DFW is the most challenging place for asthma prevalence in Texas. According to the Behavioral Risk Factors Data Portal of Center for Disease Control and Prevention (CDC), there were about 13% of adults with asthma in this region while this value was 12.5% for the entire Texas and 14% for the nation in the year 2016 (Healthy North Texas, n.d.). To address the burden of asthma in Texas, the Asthma Coalition of Texas (ACT), in partnership with the Texas Asthma Program at the Department of State Health Services (DSHS) has developed Texas Asthma Plan with different goals ranging from building awareness/educating asthma patients to provide the highest quality medical care to all Texans with asthma (Asthma Coalition of Texas 2010). Their goals also include to provide warning system during bad environment days such as in ozone action days as well as identify environmental justice issues for asthma disparities that disproportionately impact minority groups. This coalition also aims to reduce asthma exacerbation in Texas through state asthma program and identify state funding to support the program. In spite of existence of these plans and policies, the asthma problems still persist in Texas especially in DFW region.

2.4 Social Determinants of Asthma

Previous studies investigated various social determinants of health influence the burden of asthma. The detrimental factors include neighborhood disorder, socio economic condition, parental education (Ebell et al. 2017; Vo et al. 2017), community violence (Sternthal et al. 2010), financial hardship (Beck et al. 2014), stress, country of origin and family structure (Shiue 2013) Ebell et al. (2017) explored in Georgia state if particular social groups of people, particular income level, gender are mostly suffering from asthma. They used data from the Georgia Asthma Call-back Survey (ACBS), Georgia hospital and emergency department survey for asthma patients and the Behavioral Risk Factors Surveillance Survey (BRFSS). Then using univariate and multivariate logistic regression, they found asthma is prevalent among non-Hispanic, African American women who have education less than high school, annual household income below $25,000 and living in rural parts of the state. The authors also studied the relationship of asthma with healthcare services and they found patients without any insurance coverage had higher prevalence of asthma than who were insured or uninsured for less than 6 months. As the authors also collected information from the Call-back Survey data, their dataset also had information about the Body Mass Index (BMI), exercise and smoking habit. Regarding these lifestyle factors, authors found the prevalence of asthma was higher among respondents with increased BMI, current smokers and with them who did not exercise. The authors found important caveat in the state of Georgia, regarding social determinants of health and assumes affordable health insurance can help improving the management of asthma. Not much of studies have conducted to explore the social determinants of health for adult asthma patients. Studies commonly focused on children asthma and health disparities (Mcdowell et al. 2016; Sternthal et al. 2016; Vo et al. 2017). Compared to children of high SES, children exposed to family turmoil, violence, chaotic household condition are vulnerable because such socio-psychological factors trigger anxiety and asthma among children (Williams et al. 2009; Thornton et al. 2016). Moreover, increased exposure to violence predicted greater number of days with asthma symptoms in children (Williams et al. 2009). Studies on health disparities indicated asthma is more prevalent among African American children living in low income areas (Li and Newcomb 2009; Beck et al. 2014; Vo et al. 2017).

McDowell et al. (2016) investigated the influence of different socio-economic domains on the exacerbation of children asthma who were requiring admission to intensive care unit (ICU) in Cincinnati, Ohio. They collected data for 774 children from the Greater Cincinnati Asthma Risk Study. The dataset contained information about age, race, household income, parental education, indoor environmental exposures (molds, furry pet, carpeting), allergen sensitization (cat or dog dander, roaches, mouse, dust mite, ragweed, and white oak), psychosocial strain (nervousness, fatigue, irritability, worthlessness, hopelessness) and financial hardships (parents are jobless, borrowing money, do not own a house or a car). The authors conducted cross-sectional analyses using chi-square statistics or Fisher exact test comparing the children who were admitted to the ICU to those who did not require ICU admission. They did bivariate association comparison between these two groups with respect to demographics, socioeconomic indicators, hardships, allergens and indoor environmental conditions. Multivariate logistic regression analysis was performed, and a stepwise selection procedure was carried to obtain final logistic variables. The final model considered only those variables which were significant at 0.05 level. The result of their analysis showed there were no difference between ICU and non-ICU child patients with respect to race, gender, insurance status, annual income and education level. Moreover, there were no statistically significant difference between two groups with respect to healthcare use, financial difficulty and psychological distress. They only found significant difference between two groups in terms of age distribution, which the authors assume because of different pattern of "pathophysiology of wheezing" among different age groups. For ICU patients, previous treatments pattern, patient's medical history, genetic inheritance, dependence on self-reported allergen information than direct measurement are notable reasons mentioned by the authors that may have actual influence on ICU admission for children patients which were not captured by the result of their model.

Previous research have focused on different perspective of social determinants of health for children with asthma. A recent study by Newcomb and Li (2019) predicted social inequalities for adult asthma patients in north Texas area. Result of their regression model showed that, hospital visit due to asthma exacerbation is prominent among black female adults with low median family income and low education status. The authors considered only eight urban counties of north Texas region. But it would be interesting to observe the social determinants of all the counties (16 counties including both rural and urban) of North central Texas region. This can provide an overall scenario of social inequalities of adult asthma hospital admission that exist in this region and my research will attempt to investigate this aspect.

2.5 Asthma severity and exposure to pollution in North Central Texas region

Several studies on Texas and DFW region have investigated the association between asthma prevalence and exposure to different pollutants (especially Ozone O3, Nitrogen di Oxide NO2 and Particulate Matter P.M 2.5) from different perspectives such as investigation of asthma exacerbation with respect to different ozone levels and wind direction, longitudinal studies of asthma patients living in rural and urban counties, asthma discharge rate and seasonal exposure to pollutants (Gorai et al. 2015; Alhanti et al. 2016; Hudak 2014; Khunsri 2015). These studies applied different quantitative methods to observe the association between asthma severity and exposure to pollutants of different spatial and temporal variations. Dallas Fort Worth area is non-attainment for ozone, which means. It is an area that does not meet the national primary or secondary ambient air national primary or secondary ambient air quality standard for ozone pollution (U.S. Environmental Protection Agency, n.d.b). Ozone is considered to trigger asthma condition as it causes irritation to lungs and airways and according to Asthma and Allergy Foundation of America (n.d.), ozone concentration is directly related to asthma attacks. Different studies on asthma condition and ozone concentration in north Texas region have different findings about their relationship. For example, Khunsri (2015) conducted a longitudinal study for the period of 2005-2011, focusing exclusively on asthma inpatient hospitalizations in different counties of Texas. She conducted Spearman rank correlation between ozone exposure and asthma hospitalization rate. But for all types of hourly and annual concentration of ozone exposure, there were no significant correlation for either child or adult asthma rates either in rural or urban counties of DFW area.

On the other hand, in a similar study by Goodman et al (2015), they investigated the relationship between O_3 and asthma hospital admissions (HAs), and the potential impacts of outdoor pollen, respiratory infection HAs, and the start of the school year in Texas. They used daily time-series data on asthma HAs and ambient O_3 concentrations for Dallas, Houston, and Austin, Texas for the years 2003–2011. They applied Poisson generalized additive models and adjusted for temporal trends, meteorological factors, pollen, respiratory infection HAs, day of the week, and public holidays. Overall the association between total asthma HAs and O_3 concentration was not significant. But when controlled for ages and months, they found the association is significant for school going children (age 5-14 years) at the start of school years in August and September, but it was null for individuals age 15 years or older. The association did not change significantly with adjustment for pollen and respiratory infections and lost statistical significance when August and September data were excluded. By using similar concept but with different dataset, Alhanti et al., (2016) found similar association between 5-18 years age group of children with Emergency Department (ED) visits and concentration of short-term ambient Ozone for three different cities- Atlanta, GA, St. Louis, MO and Dallas, TX. The association was strong for nonwhite male children of 5-18 years old, but it was insignificant for other age groups and genders. One interesting findings of their research was that the associations between $PM_{2.5}$ concentrations and asthma ED visits were strongest for the 19–39-year age group. For measurement of $PM_{2.5}$ concentrations, they considered 24-hour average $PM_{2.5}$ ($\mu g/m^3$) for 12 counties around Dallas (year 2006-2009). They used daily time-series Poisson regression models to assess the relationship between asthma emergency department (ED) visit counts and $PM_{2.5}$ concentration along with concentration of ozone, Sulfur dioxide and Nitrogen dioxide. Except for PM 2.5, there were no significant associations between any adult age group of people for asthma ED visit and concentration of ozone, Sulfur dioxide and Nitrogen dioxide for Dallas, TX. In most of the similar researches, there were no significant relation with concentration of pollutants and asthma prevalence in north Texas region (Hudak 2014; Carls 2010). As a reason of such insignificance of models, authors considered limited number of measurement sites of pollutants may be responsible for not being able to depict the overall scenario of a region (Khunsri, 2015). Moreover, variation in temperature and airstreams in different time and season produce random patterns of pollutant concentration and eventually have impact on the results (Hudak, 2014). Moreover, as literature suggested asthma prevalence is also influenced by indoor air qualities, therefore these studies could consider the indoor air quality of asthma patients besides considering outdoor pollutant concentrations (Mckee-huger and Loosemore 2011; Casas et al. 2012; Moran et al. 1999). Focusing solely on outdoor air pollutant may not be able to capture the cumulative effect of other factors on asthma and may have impact on results.

2.6 Asthma and Transportation Variables

Epidemiologic studies have shown the association between exposure to traffic and asthma symptoms in different locations (Brauer et al. n.d.; Morgenstern et al. 2008; Gauderman et al. 2005). Previous works have shown that emissions from on-road vehicles are correlated with population density, road density, and traffic counts (Saide et al. 2009; Brondfield et al. 2012; Gately et al. 2013). Some studies have considered traffic counts or traffic volume and road density to spatially allocate vehicular emissions (McDonald et al. 2014). Very few studies have been conducted on asthma exacerbation and their relationship with traffic exposures in DFW region. In most of the cases, researchers investigated association between childhood asthma and exposure to traffic (Newcomb and Li 2008; Li and Newcomb 2009). Depending on the consideration of traffic exposure parameters and controlling for selected socio-demographic variables, the results of studies vary.

For example, Newcomb & Li, (2008) developed a logistic regression model to predict the effect of traffic exposure on the hospital admission of children with asthma in the Fort Worth Metro area. They considered residence ≤1,500 meters of a major roadway or residence farther than 1,500 meters from a major roadway as measure of exposure. Their model with binary variables showed children who lived within 1 mile (1,500 meters) of a major roadway were almost eight times more likely to be admitted for asthma than are children who live farther away. By using distance from roadways as a continuous variable, they found for every meter increase in proximity to major roadways, there is 0.1% increase in the likelihood of admission for asthma treatment. This is indicating a strong predictive effect of distance from the child's residence to a major road on the hospital utilization of children with asthma. Their recent study (Li and Newcomb, 2019) considered log transformed variables of transportation: average speed of road segments and road density (regardless of road hierarchy). The regression model output revealed that, adult asthma hospital visits increase with significant increase of these transportation parameters.

But the same group of researchers (Li and Newcomb 2009), with similar measure of traffic exposure found no significant association between traffic exposure and childhood asthma prevalence in Tarrant County (Part of Fort Worth Metro Area). Their measures of transportation exposure were road density (road length in feet per square feet area in a census block group), traffic density (average traffic counts in a census block group), and proximity to major roadways (census block groups that are within the buffer zone of 500 ft). Their model found no significant differences in measures of transportation exposure, rather results showed that increased road density is associated with reduced likelihood of having children hospital admissions. As an explanation to such findings, the authors mentioned lack of information about road type and number of lanes, as road function, traffic volume, and travel speed that affect vehicular pollution might be the reasons. Weighted road density can help overcoming such limitations, but for that, information about road types needs to be available. Different road types (arterial road, connecting road. Local road, etc.) have different functions and designed for different traffic volume and different speeds. Consideration of weighted road density can be a simple way to consider a proxy for traffic related air pollution exposure (Rose et al. 2009). Hansell et al. (2014) considered weighted sum of the lengths of road within 50 meters radius of geocoded residential addresses of children (5 and 8 years) who have allergic disease and lung function (asthma, wheezing). Within that 50 meters radius, arterial roads were given a weighting of 3, distributor roads had weighting of 2 and local roads given a weighting of 1. They used a random intercept Poisson model with robust error variance to observe the association between Weighted Road Density (WRD) and respiratory outcomes at age 5 and age 8 years. They found strong association between increased WRD and exacerbated respiratory symptoms.

Not necessarily all studies found traffic exposure or traffic related emission as a significant contributor to the asthma exacerbation. Mcdowell et al. (2016) conducted chi-square test between ICU and non-ICU children asthma patients in Cincinnati, Ohio. They considered the influence of elemental carbon attributed to traffic which is estimated by applying a validated land use regression model. But the result showed there is no difference in traffic-related air pollutant exposure elemental carbon attributed to traffic between patient groups. Authors claimed intrinsic disease factors, may be more important predictors of ICU admission.

Researches in other regions, such as in California, found traffic exposures have been associated with adverse asthma effects (McConnell et al. 2010). Some studies measured concentration of vehicular pollutants using software like CALINE4, which is available to study the concentration of pollutants at different roads in California and then by using the information of pollutant concentration, studies investigated the impact on asthma. After adjusting for Hispanic ethnicity, medical insurance, cohort, community, and relative humidity, result showed higher local NO2 concentrations were associated with higher asthma prevalence in the study area (Chen et al. 2015). Some researchers used pollutant data from device-based measurements available from regulatory monitoring stations. McConnell et al., (2010) used regional ambient ozone, nitrogen dioxide (NO2), and particulate matter data measured continuously at one central site monitor in each of 13 study areas. Children asthma risk with modeled traffic-related pollution exposure from roadways near homes and near schools indicating ambient NO2 measured at a central site in each community was not significantly associated with increased risk. Studies in other part of the USA as well as in international studies found different variations of association between traffic exposure (distance from road, traffic volume or road density) and asthma prevalence ranging from weak to strong relationship (Nishimura et al. 2013; Cai et al. 2017).

Such inconsistency of results can be explained by three major reasons. First, consideration of asthma prevalence was different for different studies such as some studies considered the hospital admission, emergency room visits or the number of asthma patients within a community. Second, consideration of traffic exposure and method for determining on road pollution widely vary from one region to another. Third, as a part of limitations, most of these studies do not have access to the genetic information or lifestyle of asthma patients which may have impact on the results.

Most of the studies on traffic exposure and asthma focused on childhood asthma. As another measure of traffic exposure, studies also considered commuting time as it has been stated that daily commute traffic is linked to asthma (Wright 2013). A study by McConnell et al. (2010) found that, increasing commuting time to school was associated with severe wheeze among children with asthma, though the association was not statistically significant as found from their logistic regression model. The authors used an online application named “Mapquest” to calculate the travel time and distance from home to school, based on the addresses of children’s home and their schools. As this tool use optimum travel route based on the shortest time by measuring distance, so it cannot capture the real traffic time. Moreover, this application cannot capture traffic volume which might have impact on speed and related travel time during the school period. According to authors, all these deficiencies in their model consideration were responsible to have different outcomes than what they hypothesized. For adults, one study considered commuting time besides considering the proximity to major roads to investigate the condition of adult asthma (Lindgren et al. 2010). In that study, Lindgren et al. (2010) observed association between living within 50 meters of road, commuting time with asthma prevalence in southern Sweden. The result of their two-stage case control cross-sectional analysis showed that, associations were not stronger when accounting for total traffic exposure that includes traffic intensity near residence, travel time, time spent at work. No scholarly researches were found for the U.S. that focused on the relation between adult asthma and commuting time. To investigate the gap, this study attempts to explore the relationship between commuting time and adult asthma in an auto oriented region like North Central Texas.

2.7 Asthma and Land Use

Besides considering roads to investigate the issues of traffic exposure, some studies incorporated land use and land cover categories to explore an integrated impact of these on the concentration of pollutants and effect on asthma (Ebisu et al. 2011; Rao et al. 2017). Like the measure of traffic exposures, consideration of different land use categories also varied from one study to other study. Some studies considered more aggregated measure to investigate the effect of land use. Such as, Khunsri (2015) by using Nonparametric statistical (the Mann-Whitney U Test) analysis revealed a clear distinction between asthma hospitalization for rural and urban counties where hospitalization rate in rural counties was higher than for the urban counties among children (<18 years) and adult (>18 years) in Dallas Fort Worth Area. The difference of rural and urban hospitalizations was statistically significant in her study.

Studies have considered more detail specification about land uses, such as land use zoning and impact on asthma severity. Maantay (2001) reviewed how land use zoning evolved in New York City and have impact on health of the citizens. He showed that in South Bronx neighborhood of New York City, residents living in a quarter mile of the largest wastewater sludge palletization plant in the Northeast and the region's largest medical waste incinerator were over five times more likely to have asthma than residents living farther away from these noxious land uses. But this study didn’t consider other categories of land uses. A comparative study by Ebisu et al. (2011) found that, among different land uses, “urban land use” (defined it by single-family housing units, apartment complexes, row houses or commercial/industrial) is strongly associated with severity of respiratory symptoms like wheezing or asthma in children but the association was not significant for grass/farm, forest or water. Similarly, Rao et al. (2017), found that, about 5% increase in green space or tree canopy can reduce the local incidence rates of asthma exacerbation by 6% and about 8% increase in high density development can increase 3% asthma exacerbation in Portland-Vancouver, OR.

Such detailed studies on land use variation and their impact on adult asthma exacerbation have not been found for the Dallas Fort Worth region. Though Newcomb and Li (2019) considered the association between urban drilling sites and adult asthma exacerbation in north Texas region, but there are other land uses categories (such as green space, industries, etc.) which are important elements of built environmental variables. Inclusion of different land use categories in my study can provide an integrated and an overall scenario about the surrounding condition and their effect on asthma hospital admission rate. Besides the parameters of outdoor environment, many studies have considered indoor air quality or environment in order to know their impact on asthma condition. This study would also provide a shed on the indoor environment in terms of available information on housing characteristics.

2.8 Asthma and Dwelling Condition

Previous studies found that, poor conditions of housing units are associated with a wide range of health concerns, including asthma and other respiratory infections (Krieger and Higgins 2002). Studies identified features of substandard housing including- absence of hot water, inadequate food storage system (absence of refrigerator), ineffective system for wastewater disposal (lack of piped sink or shower), presence of indoor allergens (mold and pests)- are related to spread of diseases such as respiratory diseases (Mckee-huger and Loosemore 2011; Diette et al. 2007; Krieger and Higgins 2002).

Different studies have considered different parameters for indoor or in-house environment of asthma patients. Besides the hygiene condition of dwelling units, studies have also considered the indoor air quality in terms of fuels used for house heating.

Previous studies have considered house heating fuel as an important parameter for indoor air quality (Shah, Debella, and Ries 2008). Free, Pierse, and Viggers (2010) investigated the association between childhood asthma and how the change in house heating fuel from conventional system to more effective heater increased school attendance for children. They used responses from survey conducted for 409 households containing asthmatic child aged 6 to 12 years. They applied generalized linear and found after converting into more effective heater system from un-flued gas heating, open fires or low-kilowatt electric heaters actually reduce winter school absence by 21% for asthmatic children in New Zealand. Another study showed, certain indoor heating fuels such as wood, coal, coke utility gas or open furnace are related to increased presence of moderate asthma among 18,617 individuals in Poland (Piekarska et al. 2020).That study also mentioned increased building age as another risk factor for asthma. The authors of that study used European Community Respiratory Health Survey (ECRHS) as a tool to collect information of asthmatic patients. After performing analysis using the contingency tables and chi-square independence test, they found there were significant increase of moderate and severe asthma in the households that were using coal, coke, utility gas or open furnace as well as for central heating system. According to them, central heating system can be a significant threat for people suffering from asthma due to reduced humidity with hot radiators and closed window. Moreover, central heating may also cause exposure to indoor allergens such as house dust mites. Accumulation of house dust mite allergens and reduced air ventilation can lead to severe asthma symptoms. That study also identified that; housings built in the years 1971-1990 are significantly related to moderate asthma occurrence. The authors assume this is may be due to use of specific raw materials and technological capabilities available during that time.

Housing age is another important parameter to indicate indoor environmental quality. Studies found older housing structures are strongly associated with mold, musty odors, secondhand smoke infiltration and roaches (Vesper, Robins, and Lewis 2020; Long 2020). These elements are known for aggravating asthma condition. Vesper, Robins, and Lewis (2020) observed a significant different between mold contamination and asthma exacerbation between newer and older homes in Detroit and non-Detroit Michigan homes. They used Environmental Relative Moldiness Index (ERMI) scale and statistically compared the mean ERMI values in Detroit and non-Detroit homes. They found, Detroit homes that were 60 years old had significantly greater mean EMRI value than Detroit homes less than 60 years old. In addition, mean EMRI value for Detroit asthmatic children patients' home was significantly greater than mean EMRI value for non-Detroit homes. This is indicating housing age was playing a vital role on asthma prevalence.

Long (2020) considered air conditioning, home age by decade, home type (apartment, mobile home, single-familty home) as housing characteristics to investigate the asthma prevalance in 25 US metropolitan areas for 9558 households available from 2015 American Housing Survey data. After performing multivariate logistic regression model, he found housing age is significantly related with mold, musty odors and secondhand smoking infiltration, and roaches. Again, these were found to strongly associated with asthma related emergency department visit for the youngest child with asthma. This is indicating housing age is connected with asthma exacerbation.

In summary, housing age is an indicator of asthma condition and studies found older housings are related to asthma exacerbation. But on the other hand, studies reported varying associations between use of different fuel for house heating and respiratory symptoms or lung function in different group of people. Though Texas is a warm state and experience mild winter, but it does not mean the weather is never cold. Interior comfort condition is maintained during heating season (Kootin-Sanwu, V., Haberl, J. S., & Kim and Haberl 2000). Moreover, such parameters have not been studied for any age groups with asthma in Dallas Fort Worth Area or any other places in Texas.

2.9 Summary

The literature demonstrated several factors (transportation, land use, outdoor environment, indoor environment, socioeconomic parameters) have impact on asthma prevalence at different degrees. Moreover, the results of the researches varied depending on how the conditions of asthma were considered such as emergency- nonemergency, ICU- non-ICU patients, children of different age groups or adults. The results also widely varied how different studies measured the factors of transportation parameters, indoor and outdoor environment, categorization of land uses, indoor or outdoor air quality parameters. Most of the literature agreed African American are the most stressed group of population with asthma severance. Literature also have consensus about several biological factors such as genetic information or health conditions obviously are important factors for asthma but due to unavailability of information for those the output of the model may widely vary.

Chapter 3 Research Design

3.1 Introduction

This chapter discusses about the process followed for the research and methods applied for analyzing data. In this chapter, discussion has been made about the research hypotheses, analytical methods, data sources and data processing for the study.

3.2 Research Hypotheses

Based on the literature and research questions discussed in previous chapters, the hypotheses of this study are as follow:

1. Hypothesis 1: Proximity to major roads is expected to influence asthma prevalence. The risk of asthma prevalence increases with the proximity to major roads due to heavy traffic and vehicular emission that have impact on asthma condition (Li et al. 2011; Brugge et al. 2007). Or in other words, the likelihood of asthma severity or emergency hospital visit is higher for the patients living near major roads (Newcomb and Li 2008). These evidences inspire the author to hypothesize that, adult asthma hospitalization rate at CBGs is high due to proximity to major highways.

   Null hypothesis 1: "There is no relationship between adult asthma hospitalization rate and proximity to major highways. The adult asthma hospitalization in CBG does not increase with the increased proximity to major highways."

2. Hypothesis 2: Previous investigations demonstrated that the amount of transportation infrastructure can influence the condition of asthma patients. Studies considered this parameter as the road density (regardless of categories of road) or weighted road density (considering hierarchy/types of roads) within certain

area. They measured it by total road length (meters) in a CBG (Newcomb and Li, 2008) or road length (ft) per unit of area (square ft) in a CBG (Li and Newcomb, 2009) or weighted sum of the length of different roads in targeted area (Hansell et al. 2014). Researchers expected that all else being equal, increase in transportation infrastructure increases traffic activities and have increased influence on asthma patients (Newcomb and Li, 2008, Hansell et al, 2014). This aspires the author to hypothesize that, adult asthma hospitalization rate is higher in CBGs that contains more roads.

*Null hypothesis 2: "*There is no relationship between adult asthma hospitalization rate and road density in a census block group. The adult asthma hospitalization in CBG does not increase with the increased road density.*"*

3. Hypotheses 3: Studies considered traffic speed as one of the parameters of traffic exposure and hence found relationship with asthma exacerbation (Gauderman et al. 2005). Moreover, traffic speed can also influence other transportation factors such as travel time or traffic volume (McConnell et al. 2010). Increased average speed of traffic in an area found to be positively associated with asthma exacerbation, that means with increased average speed of traffic there is increased asthma hospitalization rate. In this study, it is hypothesized that, adult asthma hospitalization rate is high in those census block groups where average speed of traffic in the internal roads is high.

   *Null hypothesis 3: "*There is no relationship between adult asthma hospitalization rate and average speed of traffic in a census block group. The adult asthma hospitalization in CBG does not increase with the increased average speed of traffic.*"*

4. Hypotheses 4: As this study is considering asthma in adult, therefore, the author assumes that, time spent on road for commuting have impact on adult asthma. Previous investigations indicated daily commute traffic is linked to asthma (Wright 2013; McConnell et al. 2010). So, it is hypothesized that increased average travel time in a census block group is related to increased adult asthma hospitalization rate.

   *Null hypothesis 4: "*There is no relationship between adult asthma hospitalization rate and commuter travel time in a census block group. The adult asthma hospitalization in CBG does not increase with the increased commuter travel time.*"*

5. Hypotheses 5: Studies found, with the increase of green space the incidence of asthma exacerbation reduces (Rao et al. 2017) on the other hand, asthma severity increases with the existence and proximity to hazardous land uses (such as waste management site, industrial sites) (Maantay 2001; Ebisu et al. 2011). For this study, it is hypothesized that, adult asthma hospitalization rate reduces in census block groups where land area of green spaces is high.

   *Null hypothesis 5: "*There is no relationship between adult asthma hospitalization rate and amount of green space in a census block group. The adult asthma hospitalization in CBG does not decrease with the increased amount of green space.*"*

6. Hypotheses 6: The author assumes, besides outdoor environment, consideration of indoor environments can provide an understanding about the combined impact of outdoor as well as indoor factors on asthma severity. House heating fuels are considered as important parameters for indoor environment quality (Free, Pierse,

and Viggers 2010; Shah, Debella, and Ries 2008). Previous studies investigate that use of open furnace, wood or gas as fuel can trigger asthma condition (Piekarska et al. 2020). Therefore, it is hypothesized, adult asthma hospitalization rate is high in census block groups where gas stove, coal or woods are used by most of the households for house heating as these fuels were reported to be detrimental for asthma.

*Null hypothesis 6: "*There is no relationship between adult asthma hospitalization rate and house heating fuels such as wood, coal, coke used in a census block group. The adult asthma hospitalization in CBG does not increase with the increased use of such house heating fuels.*"*

7. Hypotheses 7: Besides house heating fuels, studies considered other factors of indoor environment such as condition of kitchen or plumbing as a parameter of indoor environment. Due to hygienic issues, respiratory illness is associated with incomplete kitchen and plumbing system (Mckee-huger and Loosemore 2011). American Community Survey (ACS) and Housing and Urban Development (HUD) define incomplete kitchen and plumbing in terms of absence of any of the items such as stove/burner, refrigerator, sink with piped water, running hot and cold water, bathtub/ shower and flush toilet. In this study, it is hypothesized that, adult asthma hospitalization rate is high in those census block groups where number of dwellings with incomplete kitchen and plumbing is high.

   *Null hypothesis 7: "*There is no relationship between adult asthma hospitalization rate and number of dwellings with incomplete kitchen and plumbing in a census block group. The adult asthma hospitalization in CBG does not increase with the increased number of dwellings with incomplete kitchen and plumbing.*"*

8. Hypothesis for 8: Age of housing structure is another important indicator of indoor environment quality. Older housings are considered as dilapidated structures that found to be associated with increased adult asthma exacerbation (Newcomb and Li, 2019). Moreover, Studies found older housing structures are strongly associated with mold, musty odors, secondhand smoke infiltration and roaches (Vesper, Robins, and Lewis 2020; Long 2020). These elements are strong predictive triggers for persitent asthma (Piekarska et al. 2020; Alvarez et al. 2016; Rivera, Kawachi, and Bennett 2014). Such findings aspire the author to investigate the condition of housing structure in terms of age and its relationship with adult asthma in north Texas region. It is hypothesize that, adult asthma hospitalization rate is high in older CBGs.

   *Null hypothesis 8: "*There is no relationship between adult asthma hospitalization rate and age of housing structures in a census block group. The adult asthma hospitalization in CBG does not increase with the increased number of older housing structures.*"*

9. Hypothesis 9: Studies found asthma is prominent in black dominating, low income and low education attainment areas (Ebell et al, 2017; Beck et al, 2014; Williams et al, 2009, Li and Newcomb 2009). For the gender, the results widely varied. Some studies found asthma is predominant among male than female and some other studies found vice versa. In the north Texas region, male pediatric patients outnumber females almost 2 to 1 (Newcomb and Li, 2008) and majority of pediatric asthma patients admitted for hospital treatment were male (Li and Newcomb, 2009). For adults with asthma in north Texas region, Khunsri (2015) and Carls

(2010) found higher percent of male have asthma than female. Though the result of a very recent study by Newcomb and Li (2019) showed adult females are more likely to be admitted in hospital for asthma exacerbation than male in north Texas region. Morevoer, recent empirical evidence across the country (Rhee, H., Love, T., Groth, S. W., Grape, A., Tumiel-Berhalter, L., & Harrington 2019) as well as around the world (Habib, A. R. R., Javer, A. R., & Buxton 2016; Luu, K., Sutherland, J., Crump, T., Liu, G., & Janjua 2018; Neffen, H., Chahuàn, M., Hernández, D. D., Vallejo-Perez, E., Bolivar, F., Sánchez, M. H., ... & Pavie 2019) also showed increase of asthma symptoms among adult female patients than male . Based on the findings of different studies, it is hypothesized that, adult asthma hospitalization rate is higher in CBGs which have lower education level, lower economic status, dominated by black population, and most of the population are female.

*Null hypothesis 9: "*There is no relationship between adult asthma hospitalization rate and socio demographic condition of a census block group. The adult asthma hospitalization increases with the increased lower education level, lower economic status, dominated by black population, and female population in the CBGs.*"*

10. Hypothesis 10: Different studies on asthma condition and ozone concentration in north Texas region have different findings about their relationship. For example, Goodman et al (2015) in their research revealed that, association between ambient O3 concentrations (daily average 8 hour maximum) for Dallas, Houston, and Austin, Texas and total asthma Hospital Admissions (HAs) for all age groups was not significant. But when controlled for ages and months, they found the association is significant for school going children (age 5-14 years) at the start of school years in August and September. By using similar concept but with different

dataset, Alhanti et al., (2016) found similar association between 5-18 years age group of children with Emergency Department (ED) visits and concentration of ambient Ozone (8 h maximum in parts per billion). Such variations of findings inspired to investigate the situation of adult asthma and ozone concentration in north Texas region. Therefore it is hypothesized that, adult asthma hospitalization rate is high in census block groups of those counties which have very high ozone concentration in terms of Eight Hours Ozone high value days that meet or exceeded 71 parts per billion (ppb) in year 2014 (the U.S Environmental Protection Agency (EPA) sets the standard of the primary 8-hour ozone standard and the range for "Unhealthy for Sensitive Groups" begin at 71 ppb (EPA-https://www.epa.gov/sites/production/files/2015-10/documents/20151001_air_quality_index_updates.pdf)).

Null hypothesis 10: "There is no relationship between adult asthma hospitalization rate in CBGs and concentration of ozone in counties. The adult asthma hospitalization in CBG does not increase with the increased ozone concentration in pertinent counties."

11. Hypothesis 11: Researchers studied relationship between asthma condition and concentration of PM coming from different sources. Williams et al (2019) used a nationwide panel dataset of 2,874 individuals with asthma and their exposure to $PM_{2.5}$ concentration between 2012 and 2017. They found that, 12 percent (1 $\mu g/m^3$) increase in weekly exposure to $PM_{2.5}$ was correlated with a 0.82 percent increase in weekly inhaler use (indicator of asthma exacerbation). For the North Texas Region, Alhanti et al (2015) considered 24-hour average $PM_{2.5}$ ($\mu g/m^3$) for 12 counties around Dallas (year 2006-2009). They found in Dallas region, the

associations between $PM_{2.5}$ concentrations (µg/m³) and asthma Emergency Department (ED) visits were strongest in the 19–39-year age group. Such variations of findings inspired to hypothesize that, the adult asthma hospitalization rate is high in census block groups of those counties which have higher PM 2.5 concentration in terms of Average daily density of fine particulate matter in micrograms per cubic meter (µg/m³).

*Null hypothesis 11: "*There is no relationship between adult asthma hospitalization rate in CBGs and concentration of $PM_{2.5}$ in counties. The adult asthma hospitalization in CBG does not increase with the increased $PM_{2.5}$ concentration in pertinent counties.*"*

3.3 Analytical Approach

This research considered the geographical variation of adult asthma in terms of their hospital admission in North Central Texas region for the year of 2014. This research applied different quantitative methods including descriptive statistical analysis, multiple linear regression model, and spatial cluster analysis. Correlation analyses were also conducted among variables to observe the multicollinearity. Multi-level modeling/Hierarchical Linear Regression was applied as the main model of this research to observe the combined influence of variables of different geographic levels on adult asthma exacerbations. The structure of the model is shown in Figure 3.1:

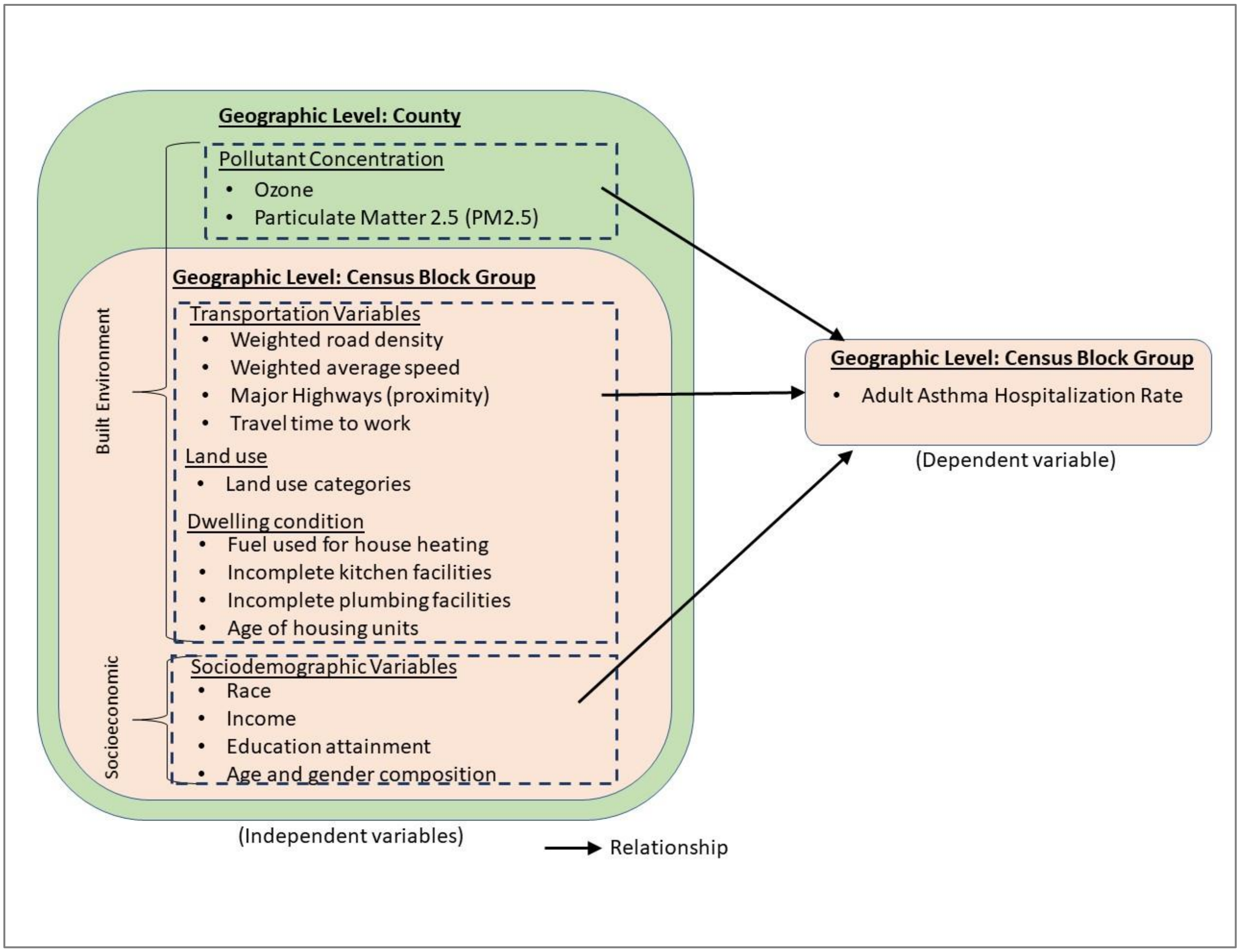

Figure 3-1 Conceptual Framework of the variables nested within Multilevel/ Hierarchical Structure of the Model

The dependent and independent variables for Multilevel/Hierarchical Linear Regression model are:

<table>
<tr><td rowspan="2">Dependent Variable</td><td colspan="2">Independent Variables</td></tr>
<tr><td>Level 1 (Census Block Group)</td><td>Level 2 (County)</td></tr>
<tr><td>Adult Asthma Hospitalization Rate in CBG= (number of each unique patient admitted in Hospital /Total adult population of pertinent CBG) * 100</td><td><u>Transportation Variables</u>
• Weighted road density
• Proximity to major highways
• Travel time to work
• Weighted average speed
<u>Land Uses</u>
Land use categories
<u>Dwelling Condition</u>
• Fuel used for house heating
• Incomplete plumbing facilities
• Incomplete kitchen facilities
• Age of housing units
<u>Socio demographic variables</u>
• Race
• Median household income in the past 12 months
• Population aged 25 and over without a high school diploma
• Female aged 18 and older</td><td><u>Pollutant Concentration</u>
• Ozone (maximum value of Eight Hours Ozone high value days)
• PM 2.5(average daily density in µg/m³)</td></tr>
</table>

3.4 Data Collection

For this study, data were collected from different secondary sources which has been listed in table 3-1.

Table 3-1 Required Data for the study and data sources

Category	Variables	Available Geography	Data Sources
Adult Asthma Hospitalization Rate in CBG	Location of Asthma Patients	Individual	Dallas Fort Worth Hospital Council Foundation (DFWHCF)
	Population	Census Block Group	American Community Survey (ACS) 5-year estimates 2010-14 (B00001e1: unweighted sample count of the population: Total: Total population -- (Estimate))
Transportation variables	Lengths of Different categories of road (for Weighted Road Density)	Road or Links/CBG	North Central Texas Council of Government (NCTCOG)
	Major Highways	Road or Links/CBG	North Central Texas Council of Government (NCTCOG)
	Traffic speed in different roads	Road or Links/CBG	North Central Texas Council of Government (NCTCOG)
	Travel time to work	Census Block Group	American Community Survey (ACS) 5-year estimates 2010-14 (B08303e1: Travel Time to Work: Total: Workers 16 years and over who did not work at home -- (Estimate))
Land uses	Land Use categories	Census Block Group	North Central Texas Council of Government (NCTCOG)
Dwelling condition	House heating fuels	Census Block Group	American Community Survey (ACS) 5-year estimates 2010-14 (B25040e2 to B25040e10: HOUSE HEATING FUEL: Utility gas: Occupied housing units -- (Estimate))
	Incomplete plumbing facilities	Census Block Group	American Community Survey (ACS) 5-year estimates 2010-14 (B25047e3: Kitchen Facilities for All Housing Units: Lacking complete kitchen facilities: Housing units -- (Estimate)
	Incomplete kitchen facilities	Census Block Group	American Community Survey (ACS) 5-year estimates 2010-14 (B25051e3: Plumbing Facilities for All Housing Units: Lacking complete plumbing facilities: Housing units -- (Estimate))
	Housing Age	Census Block Group	American Community Survey (ACS) 5-year estimates 2010-14 (B25034e6: YEAR STRUCTURE BUILT: Built 1970 to 1979: Housing units -- (Estimate))
	Race	Census Block Group	American Community Survey (ACS) 5-year estimates 2010-14 (B02001e2:

Category	Variables	Available Geography	Data Sources
Socio demographic variables			Race: White alone: Total population -- (Estimate); B02001e3: RACE: Black or African American alone: Total population -- (Estimate))
	Median HH income in the past 12 months	Census Block Group	American Community Survey (ACS) 5-year estimates 2010-14 (B19049e1: MEDIAN HOUSEHOLD INCOME IN THE PAST 12 MONTHS (IN 2014 INFLATION-ADJUSTED DOLLARS) BY AGE OF HOUSEHOLDER: Total: Households -- (Estimate))
	Population aged 25 and over without a high school diploma	Census Block Group	American Community Survey (ACS) 5-year estimates 2010-14 (B15003e16: Educational Attainment for The Population 25 Years and Over: 12th grade, no diploma: Population 25 years and over -- (Estimate)
	Female aged 18 and older	Census Block Group	American Community Survey (ACS) 5-year estimates 2010-14 (B01001e31: SEX BY AGE: Female: 18 and 19 years: Total population -- (Estimate))
	Male aged 18 and older	Census Block Group	American Community Survey (ACS) 5-year estimates 2010-14 (B01001e7: Sex by Age: Male: 18 and 19 years: Total population -- (Estimate))
Pollutant Concentration	Ozone (maximum value of Eight Hours Ozone high value days)	County	Texas Commission of Environmental Quality (TCEQ)
	PM 2.5(average daily density in µg/m^3)	County	Key Finding Reports: County Health Rankings and Road Maps

3.5 Data Processing

After collecting the data, data cleaning and data processing were required to arrange the data in a suitable format. Data were available from secondary sources as mentioned in the previous section. To collect and conduct research for asthma data which was available from the Dallas Fort Worth Hospital Council Foundation (DFWHCF), I completed the training of Collaborative Institutional Training Initiative (CITI) and completed the Texas Health Resource Institutional Review Board (IRB) protocols. Data for adult asthma was available in a geodatabase but the addresses recorded in the database was not in a consistent format. Individual addresses were needed to check and needed to bring them into a common format.

3.5.1 Data Cleaning

Asthma data was provided by the DFWHCF and data was checked for sixteen counties (Wise, Denton, Collin, Hunt, Palo Pinto, Parker, Tarrant, Dallas, Rockwall, Erath, Hood, Johnson, Ellis, Kaufman, Somerville, Navarro). There were around 17500 records for those sixteen counties (including homeless, POBox, blank information). In the available dataset, the addresses listed in "AddressLin" field was checked. The records for "homeless, PObox and blank addresses" were excluded from farther consideration.

For the rest of the data, the addresses had case sensitive or spelling issues as follow:

Case sensitive or spelling issues	5302 Hirry Hynes Bl. 5302 HARRY HINES BLVD.

The correct addresses were checked from Google Map Search (as shown in the figure 3). To check different addresses, the Zip Code and City were also used to precisely find the correct location of the asthma patients.

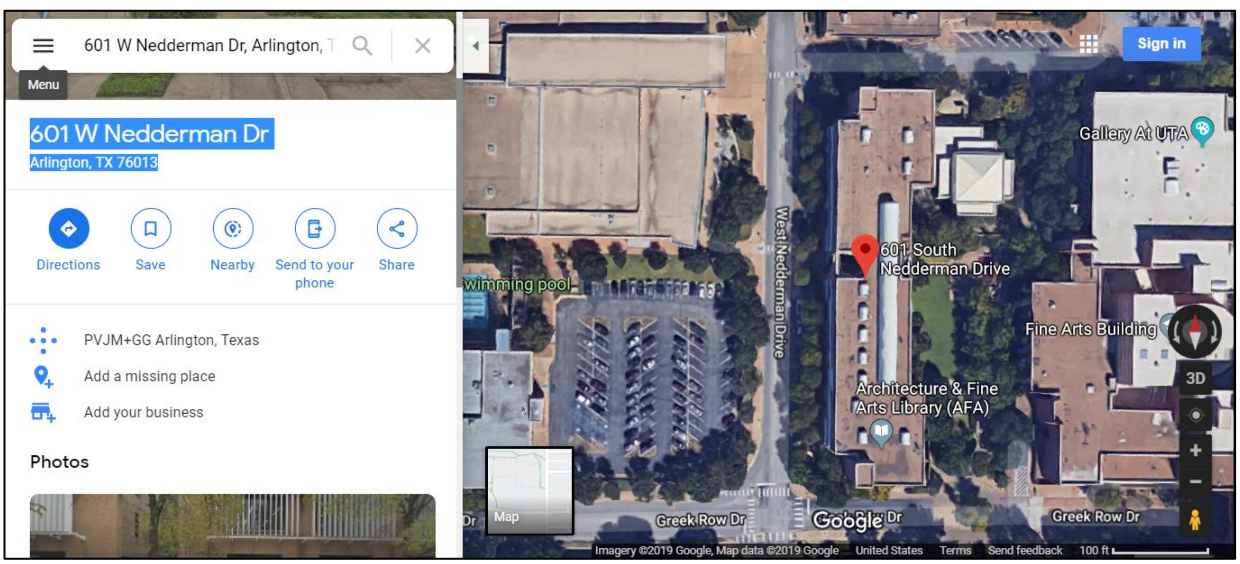

Figure 3-2 Searching the correct address from Google Map

A separate field (named: AddressChecked) was created in GIS attribute table to record the correct address collected from the Google Map. The searching results were like the following example. Demonstrating an example with one of the buildings of UT Arlington as it was not allowed to mention street addresses associated with individual patients that may identify them.

Google Map Search	601 WNethermann DO = 601 W Nedderman Dr 601 W Nedderman Drive

About 16700 data were checked and the correct addresses were recorded in GIS interface. Through such an extensive data cleaning process all the addresses were checked individually and recorded in GIS attribute table. After that, those addresses were needed to geocode in ArcGIS.

3.5.2 Geocoding the location of asthma patients

As the checked addresses, name of the city, state and zip codes were in different fields of the attribute table, therefore they needed to be into one field in order to have the full address (like: 601 W Nedderman Dr Arlington TX 76013) to geocode all of them. There are many ways to combine the information of different columns into one column and get the latitude and longitude information from the full addresses and a tool of Google sheet's extension, named "Awesome Table" was used for this study. This is an extension tool which needs to be added in the browser. Before using this tool, an excel spreadsheet from the attribute table was saved and in the excel file arranged the columns of "Address Checked", City, State, PtZip in sequence. After uploading the spreadsheet as google spreadsheet in google drive, used the option of awesome table mentioning "Are your addresses in multiple column?" Then cleaned up all the default check ins and followed this sequence of process:

Used only: Address Checked, City, State, PtZip> Insert Column (It will give the Full Address of this Format: Address Checked City State PtZip) >Click Geocode. The output is the latitude and longitude information of the addresses.

If any of the output addresses faced any error, then checked those addresses in google map, pasted the correct address found from searching. Also, in some cases, the latitude and longitude of some addresses from Texas Commission on Environmental Quality (TCEQ) were checked. Then used “Try Wider Result” option to get the best match for the errors making addresses. After that, Latitude and Longitude for all the addresses were got in that google sheet file. After getting the latitude and longitude values, saved or downloaded the file as Microsoft excel.

Then opened that MS excel file. Saved it as CSV. Added the CSV file in ArcMap. From the ArcToolbox, used “Make XY Event Layer”. Then fixed the Geographic Coordinate System using another existing shapefile or from the favorite. (Used: GSC_North America 1983). The geocoded addresses were then visible in the ArcMap. Then right click on the layer>Export Data> Save as shapefile. The output map is as below (Figure 4) showing location or home addresses of asthma patients living in NCT/DFW region:

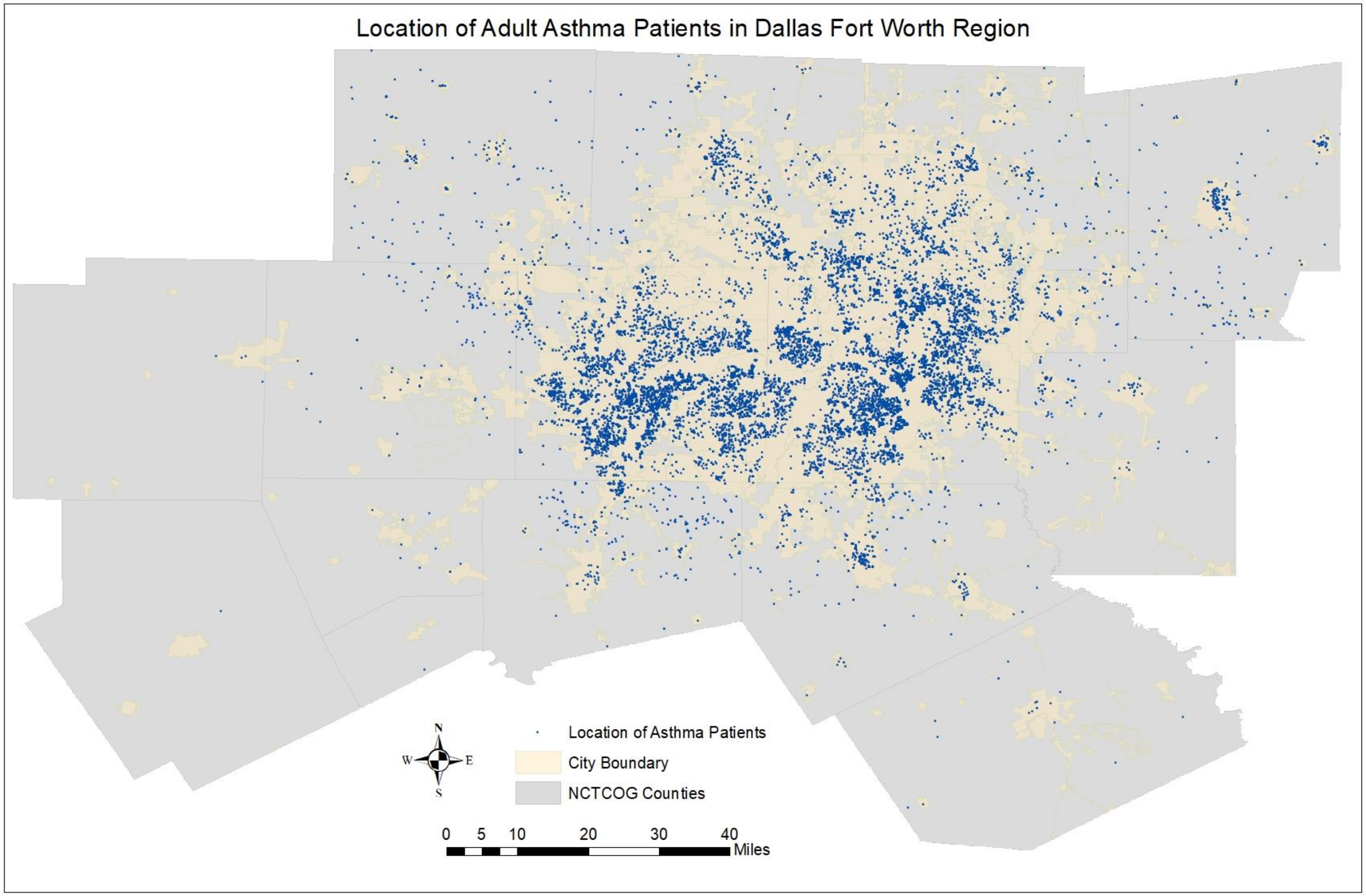

Figure 3-3 Geocoding the addresses of adult asthma patients in NCT or DFW region

3.5.3. Calculation of dependent variable

After geocoding the location of asthma patients, I was able to calculate the dependent variable. The unit of analysis of this research is Census Block Group (CBG). The collected data from DFWHCF is about hospital admission of asthma patients who are living in different locations of north central Texas. The hospital admissions were indicators of asthma exacerbation, that is, condition of patient is severe enough to get admitted to the hospitals. Data for the year 2014 were considered in this research. The patients have unique identifier number and some patients admitted to the hospitals for multiple times. In this research, number of each unique patient were considered which means patients with multiple admissions will be counted at once. Then, this unduplicated number of patients were considered with respect to the adult population of pertinent CBG. To investigate the adult asthma exacerbation in North Texas region, adult asthma hospitalization rate with respect to CBG adult population was measured as follow:

Adult Asthma Hospitalization Rate in CBG= (number of each unique asthmatic patient admitted in Hospital /Total adult population of pertinent CBG) * 100

Data processing and calculation of different independent variables are discussed in pertinent chapters.

3.6 Summary

The association between asthma and surrounding environment is a complex phenomenon. Based on the available data for both indoor and outdoor environment, I tried to explore this relationship. As data is available from different geographic level, therefore, to incorporate data into research model and to explore influence of built environmental variables of different geographical level, I applied Multilevel modeling or Hierarchical regression modeling. A detail discussion about processing of each variable and benefits of applying HLM model are discussed in pertinent chapters.

Chapter 4 Overview of adult asthma patients and social determinants

4.1 Introduction

One of the interesting aspects of public health issues is the demography of the patients. I was interested to explore which group of people were affected most in the NCT region. For this, I conducted a descriptive analysis of the patient sample. This chapter includes discussion about the most distressed group of people as well as existence of social determinants of health in this region. The health inequity was explored based on the race and gender of the patients. In addition to that, type of insurance used during hospitalization was considered as a proxy to reflect patients' economic condition and their access to health services.

4.2 Characteristics of adult asthma patients and social determinants

In this study, the asthma population consists of unduplicated hospital admission records of adult between 18 and 65 years old admitted for treatment of asthma from January 1, 2014 through December 31, 2014. Data on adult asthma patients were obtained from the Dallas/Fort Worth Hospital Council Foundation (DFWHCF) and consisted of variables associated with 56 hospitals surrounding the Dallas/Fort Worth metropolitan area. This study includes 11697 unduplicated records of individual asthma patients with their valid addresses within 16 counties of north central Texas area.

In the given data of asthma patients, age of individual patient and their gender were available. Also, the age group of individual patients were recorded. There were total eleven age groups as shown in Figure 4-1. The Figure 4-1 exhibits the percentage of male and female patients with respect to their age groups. Figure 4-2 represents the age-gender composition of general population in all the CBGs of North Central Texas region that is available from ACS-5 year estimates 2010-14.

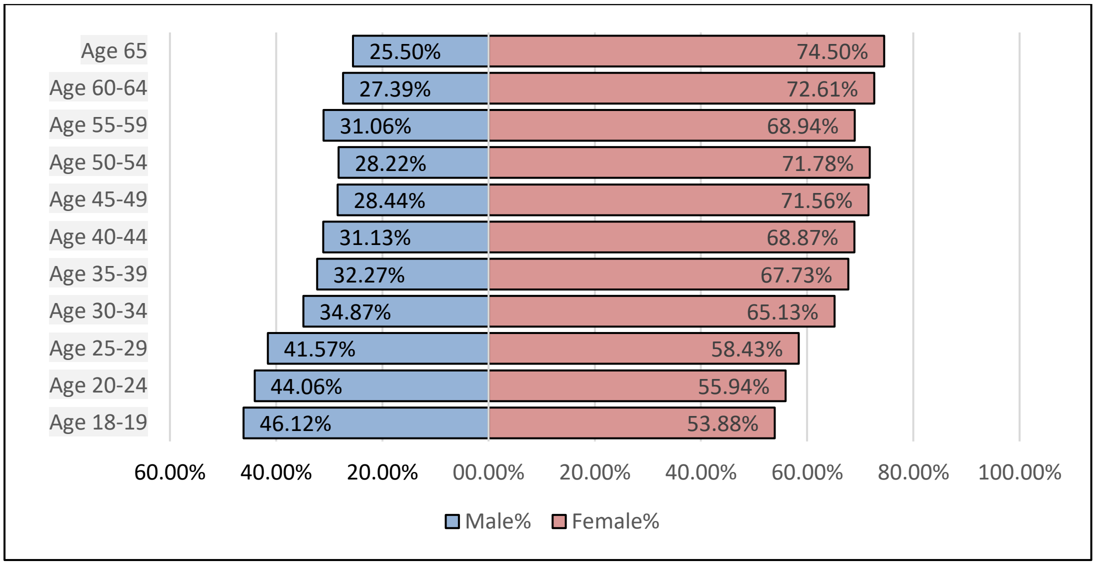

Figure 4-1 Age-Gender composition of adult asthma patients

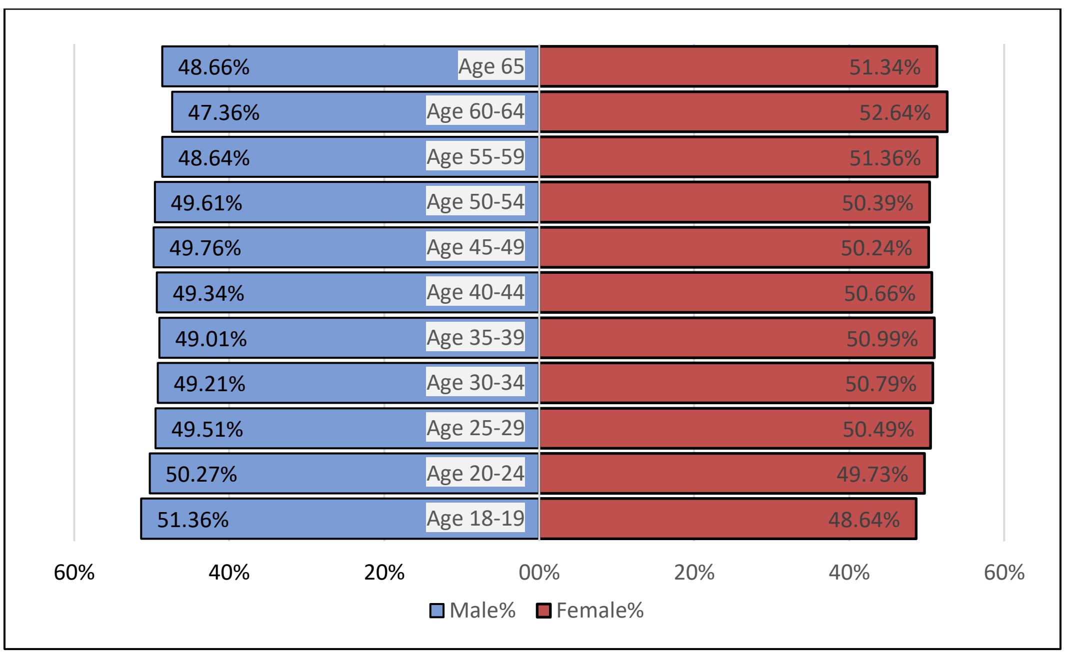

Figure 4-2“Age-gender” composition of general adult population in north central Texas

It is evident from the Figure 4-1 that, female asthma patients share the largest portions of every age cohorts. Though from the Figure 4-2, it is obvious that in general population of north central Texas, the male female ratio in every age group is almost equal (around 50%). But according to asthmatic patients' profile, apparently women are the most sufferer. In age group of 65 years, around 74% were female, which is the largest percentage among all age groups. In 18-19 years age group, 54% were female. This is the lowest percentage of female in all the age groups but still higher than their male counterparts. In addition to the Figures above, Table 4-1 provides number and gender of patients as well as age-number composition of adult population in north Central Texas. Among all the age cohorts, maximum number (1632) of patients are from 20-24 years age group (as shown in Table 4-1). Patients from this group consists around 14% of all the hospitalized asthma patients. In this age group, 56% patients are female, and 44% patients are male. The race gender composition of patient is also interesting.

Table 4-1 Age-gender composition of adult asthma patients and general adult population in north central Texas

Gender / Age group	Unduplicated adult (age 18-65 years) asthma patient			General Adult population (age 18-65 years) in North Central Texas, according to ACS 5-year estimates 2010-14		
	male	Female	Total	Male	Female	Total
Age 18-19	291 (46.12%)	340 (53.88%)	631	92939 (51.36%)	88033 (48.64%)	180972
Age 20-24	719 (44.06%)	913 (55.94%)	1632	231650 (50.27%)	229133 (49.73%)	460783
Age 25-29	658 (41.57%)	925 (58.43%)	1583	246798 (49.51%)	251711 (50.49%)	498509
Age 30-34	462 (34.87%)	863 (65.13%)	1325	247969 (49.21%)	255951 (50.79%)	503920
Age 35-39	395 (32.27%)	829 (67.73%)	1224	242148 (49.01%)	251899 (50.99%)	494047
Age 40-44	358 (31.13%)	792 (68.87%)	1150	247611 (49.34%)	254226 (50.66%)	501837
Age 45-49	329 (28.44%)	828 (71.56%)	1157	241194 (49.76%)	243510 (50.24%)	484704
Age 50-54	322 (28.22%)	819 (71.78%)	1141	232768 (49.61%)	236459 (50.39%)	469227
Age 55-59	296 (31.06%)	657 (68.94%)	953	190717 (48.64%)	201394 (51.36%)	392111
Age 60-64	206 (27.39%)	546 (72.61%)	752	151740 (47.36%)	168633 (52.64%)	320373
Age 65	38 (25.50%)	111 (74.50%)	149	51360 (48.66%)	54191 (51.34%)	105551

Table 4-2 presents race-gender composition of adult asthma patients. It is evident from the table that, female patients are also prominent in race-gender composition.

Table 4-2 Race-gender composition of adult asthma patients in north central Texas, 2014

Gender \ Race			American Indian / Eskimo / Aleut	Asian or Pacific Islander	Black	White	Other	Total
Gender	Female	Count	22	92	3147	3857	504	7623
		% within Female	0.30%	1.20%	41.30%	50.60%	6.60%	100.00%
		% within Race	88.00%	60.50%	62.30%	67.80%	64.50%	65.20%
		% of Total Patients	0.20%	0.80%	26.90%	33.00%	4.30%	65.20%
	Male	Count	3	60	1906	1828	277	4074
		% within male	0.10%	1.50%	46.80%	44.90%	6.80%	100.00%
		% within Race	12.00%	39.50%	37.70%	32.20%	35.50%	34.80%
		% of Total Patients	0.00%	0.50%	16.30%	15.60%	2.40%	34.80%
Total		Count	25	152	5053	5685	781	11697
		% within Gender	0.20%	1.30%	43.20%	48.60%	6.70%	100.00%
		% within Race	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
		% of Total	0.20%	1.30%	43.20%	48.60%	6.70%	100.00%

The percentage of female patient was highest within American Indian/Eskimo race (88%). For all other races, percentages of female patients were more than 60%. Within white race almost 68% were female and within black race almost 63% were female. Male patients had higher percentage in black race (38%) than white race (32%). Though, it was evident that black-female patients had significantly more possibility to be admitted to hospital for asthma than white-female patients ($\chi 2 = 44.38$, $p = .000$).

In addition to this, when comparing with respect to the total adult population of all the CBGs of north central Texas region, it is evident from the Table 4-3 that, percentage of total female population was high in the region (51.43%) than male (48.57%). In census block groups with or without asthma patients, the percentage of male (48%) and female

(52%) patients were same in both cases. But the ratio was higher for female (65.20%) than male (34.80%) when comparing individual patients' information.

The higher ratio of women with asthma incidence has been consistently reported by many literatures for many years and for various countries (Abraham, B, JM Anto, E Barreiro, EHD Bel, G Bonsignore, J Bousquet 2003; Santillan and Jr 2003; Pignataro et al. 2017) (Abraham, B, JM Anto, E Barreiro, EHD Bel, G Bonsignore, J Bousquet 2003; Santillan and Jr 2003; Pignataro et al. 2017). Previous studies discussed that, basically female hormones are responsible for such susceptibility of their health towards asthma (Zein, Denson, and Wechsler 2019; Koper, Hufnagl, and Ehmann 2017). Hormonal factors or level of progesterone and estradiol hormones in female body during the menstrual cycle, puberty, during pregnancy and menopause are connected with respiratory symptoms (Zein, Denson, and Wechsler 2019; Tan, Mcfarlane, and Lipworth 1997). At younger age and before puberty, asthma is common among boys and after puberty it is common in women (Zein, Denson, and Wechsler 2019). Male hormones have protective effects against asthma than female hormones and this includes effect on cellular immune system (Koper, Hufnagl, and Ehmann 2017).

Table 4-3 Characteristics of adult asthma patients with respect to adult population of CBGs, 2014

	Unduplicated Patients	All CBGs of NCT	CBGs with Asthma Patients	CBGs without Asthma Patients
Gender				
Female	7623 (65.20%)	2554467 (51.43%)	2073718 (51.49%)	480749 (51.20%)
Male	4074 (34.80%)	2412076 (48.57%)	1953858 (48.51%)	458218 (48.80%)
Race				
White	5685 (48.60%)	4756487 (71.79%)	3752733 (69.47%)	1003754(82.05%)
Black	5053 (43.20%)	1013992 (15.31%)	937532 (17.36%)	76460 (6.25%)
American Indian	25 (0.20%)	31480 (0.48%)	25785 (0.48%)	5695 (0.47%)
Asian	152 (1.30%)	381753 (5.76%)	294866 (5.46%)	86887 (7.10%)
Other	781 (6.70%)	441460 (6.66%)	390907 (7.24%)	50553 (4.13%)

From table 4-2 and 4-3, it is obvious that, among the total number of patients, the proportion of black (43.20%) and white (48.60%) patients were almost same. But when I compared the information of patients with respect to the total black or white population of all the CBGs of north central Texas, then it was evident that, black population is only 15% of all the races in this region while white population is 72%. With that, 15% of regional population, black accounted for 43% of adult asthma patients (Table 4-3). In such white dominating area, percentage of black asthma population is almost equal to the percentage of white asthma patients. This is indicating stressful condition of black in north central Texas region in terms of asthma severity.

The distressed condition of different races can also be considered with comparison of insurance the patients used during their hospitalization. The type of insurance would reflect their income as well as access to health facilities. A comparative analysis of race and different insurance types are shown in Table 4-4.

Table 4-4 Access to health facilities with different types of insurance for different races

Race \ Pay group			Pay Group				
			Insured	Medicaid	Medicare	Uninsured	Total
Race	American Indian / Eskimo / Aleut	Count	7	3	1	14	25
		% within race	28.00%	12.00%	4.00%	56.00%	100.00%
		% within pay group	0.20%	0.20%	0.10%	0.30%	0.20%
		% of Total	0.10%	0.00%	0.00%	0.10%	0.20%
	Asian or Pacific Islander	Count	57	24	3	68	152
		% within race	37.50%	15.80%	2.00%	44.70%	100.00%
		% within pay group	1.30%	1.60%	0.40%	1.30%	1.30%
		% of Total	0.50%	0.20%	0.00%	0.60%	1.30%
	Black	Count	1529	807	398	2319	5053
		% within race	30.30%	16.00%	7.90%	45.90%	100.00%
		% within pay group	35.70%	52.50%	49.00%	45.80%	43.20%
		% of Total	13.10%	6.90%	3.40%	19.80%	43.20%
	Other	Count	279	104	25	373	781
		% within race	35.70%	13.30%	3.20%	47.80%	100.00%
		% within pay group	6.50%	6.80%	3.10%	7.40%	6.70%
		% of Total	2.40%	0.90%	0.20%	3.20%	6.70%
	White	Count	2409	600	386	2290	5685
		% within race	42.40%	10.60%	6.80%	40.30%	100.00%
		% within pay group	56.30%	39.00%	47.50%	45.20%	48.60%
		% of Total	20.60%	5.10%	3.30%	19.60%	48.60%
Total		Count	4281	1538	813	5065	11697
		% within race	36.60%	13.10%	7.00%	43.30%	100.00%
		% within pay group	100.00%	100.00%	100.00%	100.00%	100.00%
		% of Total	36.60%	13.10%	7.00%	43.30%	100.00%

It is to be mentioned that Insured indicates private insurance, Medicaid and Medicare are public insurance; uninsured means self-pay or have no resource to have access to health insurance.

It is evident from the above table that, minority groups such as American Indian and Black are mostly uninsured. About 56% American Indian and 46% Black adult asthma patients were uninsured within respective races. This could be related to lack of resources to afford health insurance for primary health care. On the other hand, percentages of privately insured (42%) and uninsured (40%) white adult asthma patients were almost same. If compared across type of insurances, about 56% white patients were privileged to have private insurance while this percentage was very low for American Indian (0.2%), Asian (1.3%) and Black patients (36%). Such disparities indicate unequal access to health facilities for different races.

More aspects of health disparity of adult asthma patients in terms of race, median household income and education at census block group level were explored in next chapters.

4.3 Summary

The descriptive analysis of adult asthma patients' sociodemographic condition exhibited that health inequity exists in the north central Texas. Females of black race are vulnerable since they found to be suffering mostly. They have more possibility to be affected by severe asthma attacks that may require them to be hospitalized. A recent study on adult asthma in north Texas also found adult males are less likely than adult females to be admitted to hospital for asthma exacerbation (Newcomb P. and J. Li 2019b). My research confirms this finding.

Besides gender, there is disparity in access to health facilities for different races. Minority groups are less privileged to have any private insurance. Rather, a very high percentage of patients from minority races were not insured and hence assuming did not have access to health facilities.

There are many folds of such disparities in the society and in this case, it is affecting health. The aspects of such health discrepancies were evident not only at individual patient level but also in neighborhood level. Those neighborhood level determinants were explored and discussed in next chapters.

Chapter 5 Adult asthma hospitalization and land use

5.1 Introduction:

This study seeks to investigate the association between adult asthma hospitalization and land uses. The land use pattern in north central Texas region widely varies. In this chapter, I tried to explore distribution of different land uses in this region and how those land uses can influence the adult asthma hospital visits. Moreover, in this chapter, I also presented hotspots of adult asthma hospitalization rate and land use patterns in those hotspots.

5.2 Land Uses in North Central Texas Region

In my research, I considered the land use category inventory developed by the NCTCOG for this region. The GIS based land use data is available from NCTCOG's Regional Data Center. Their land use inventory determines the dominant use of each land parcels within 16 counties of NCTCOG region. They acquired the land parcel data from local appraisal districts and verified the data from additional data sources such as U.S Geological Survey (U.S.G.S.) or from the data developed by the Research and Information Services (RIS) department (NCTCOG 2017).

According to the NCTCOG, their land use codes originally developed based on U.S.G. S's land classification system and they have extended the codes for two main purposes. First, to provide a uniform base for interpreting urban land use that can be acceptable to different users. Second, the codes include remotely sensed (satellite) non-urban land cover data of the region that can be useful in future. Though, they have mentioned about these two purposes, but their current codes are better at delineating urban uses than non-urban land coverages. Therefore, their inventory is more appropriate to describe the term "land uses" than "land cover"(NCTCOG 2017).

The land use categories and their brief descriptions considered in this research has been listed in Table 5-1 below. The list contains 33 different categories of land uses determined by the NCTCOG. In my research model, I have considered all those detail categories of land uses. The reason for considering the detail land uses is to better understand the association of adult asthma hospitalization condition with particular land use type. Merging similar categories of land uses (such as merging single family, residential acreage, multifamily residential and mobile home into broad residential category) may create problem of generalization bias. Rather than observing the association with a generalized land use, it would be more interesting to observe which detail land use category has strong association with adult asthma hospitalization and investigate the reason behind it.

Table 5-1 Description of Detail Land Use Categories in North Central Texas Region

SL	**Land Use**	**Brief Description by NCTCOG (2017)**
1	Airport	Airport terminals
2	Cemeteries	Dedicated burial places
3	Commercial	combination of office and retail uses
4	Communication	Radio, television, cable, and telephone facilities and lines
5	Education	All public and private schools
6	Farmland	Land used for growing crops or suitable for such activities
7	Flood control	Major flood control structures including levies, flood channels, and dams
8	Group quarters	Nursing homes, group homes, college dormitories, jails, and military base personnel quarters
9	Hotel/motel	Hotels, motels, and lodges
10	Improved acreage	Land that is mostly undeveloped yet includes a non-residential structure with road access
11	Industrial	Manufacturing plants, warehouses, salvage yards, quarries, and mines
12	Institutional/semi-public	Churches, governmental facilities and offices, museums, hospitals, medical clinics, libraries, and military bases
13	Landfill	Sanitary landfills, land applications, and similar waste management facilities
14	Large stadium	Large venues for organized events
15	Mixed use	Areas that contain both commercial activities, such as office or retail, along with residential uses in the same facility or as part of the same development
16	Mobile home	freestanding units
17	Multi-family	Apartments, condominiums, residential hotels, and single family attached

18	Office	administration functions
19	Parking	Large (at least one acre) paved areas dedicated to vehicle parking
20	Parks/recreation	Public and private parks, golf courses, public and private tennis courts and swimming pools, and amusement parks
21	Railroad	Railroad lines and stations and rail-to-truck transfer facilities
22	Ranch Land	Currently in use or suitable for breeding and raising of livestock
23	Residential acreage	Land that is mostly undeveloped yet includes a mobile home, house, or other residence as a minor part of the use.
24	Retail	trade and services
25	Runway	Airport runways
26	Single family	detached single family units and duplexes
27	Small water bodies	Lakes, rivers, and ponds of at least 10 acres
28	Timberland	Land covered by trees
29	Transit	Passenger rail and bus lines and facilities
30	Under construction	construction is in progress on the site
31	Utilities	Sewage treatment, water treatment, and power plants; power line easements; and pumping
32	Vacant	Undeveloped land
33	Water	Lakes, rivers, and ponds of at least 10 acres

Source: NCTCOG (2017)

In this research, a neighborhood is defined as census block group. The total number of census block group in north central Texas is 4251. But for my research purpose, I considered only those CBGs that are associated with asthma patients, so the final sample consisted of 3296 CBGs. I considered only those CBGs that had unduplicated hospitalized adult asthma patients. I considered land use for those CBGs only. The Figure 5-1 depicts the proportion of different land uses in the targeted CBGs.

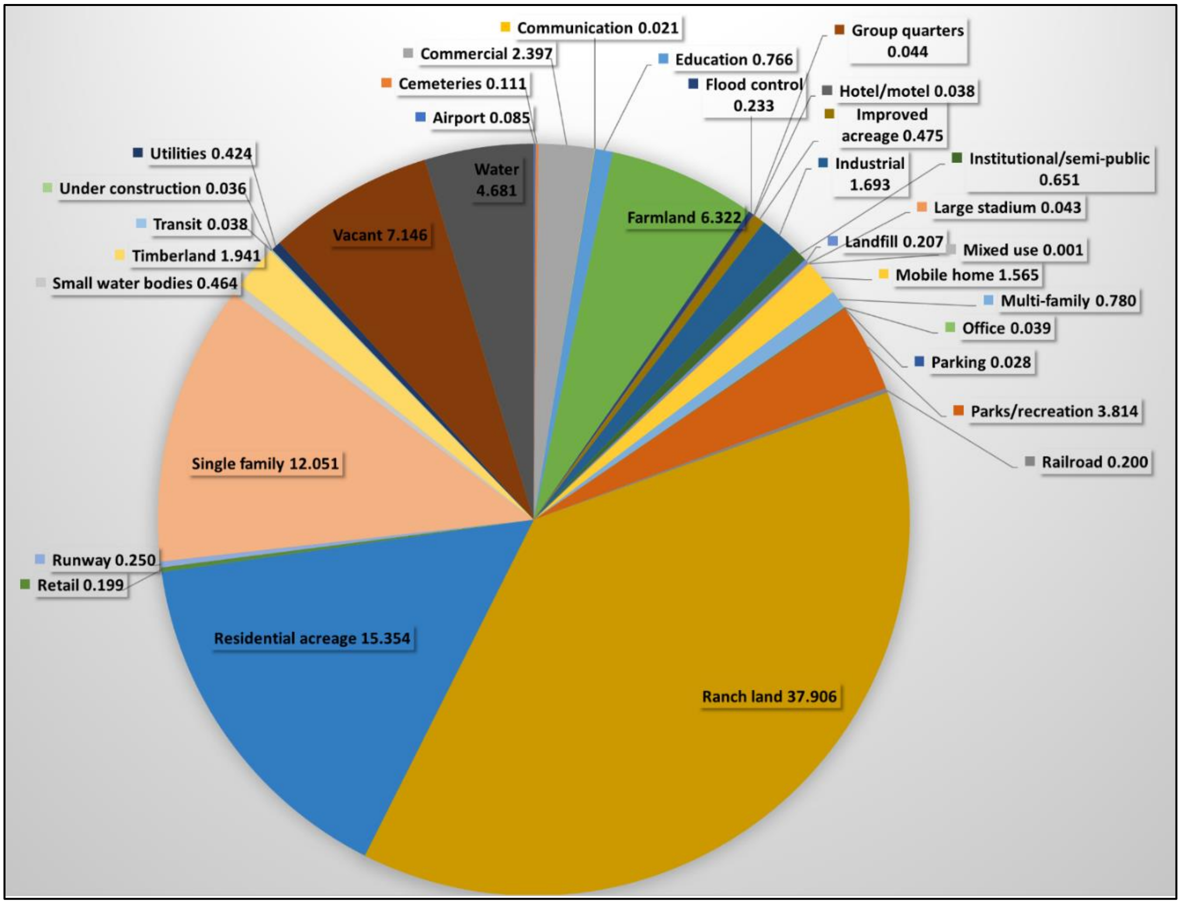

Figure 5-1 Proportion of different land uses in CBGs with adult asthma hospitalization

It is evident from the Figure 5-1 that, the largest portion (37.9%) of land in the selected CBGs of this region is occupied by ranches. Those lands are currently in use or suitable for breeding and raising of livestock. This category of land is followed by residential acreage (occupies 15% area). The NCTCOG recognized this land category mostly as undeveloped one which may include a mobile home, house or other residential structure as a very insignificant part of it. The third most used land is for single family residential purpose (12% areas of the selected CBGs). Detached single family units are covering most of the land in this sprawling region. Other types of residential uses, such as multi-family residential and mobile homes are covering 0.78% and 1.56% areas respectively. Besides these, many lands are lying as vacant or undeveloped lands (7%) in between other types of land uses.

Around 6% lands are being used for growing crops or for such activities. About 5% of the selected census block groups are occupied by different lakes, river or other type of waterbodies that are at least of 10 acres. Other important types of land uses, such as education, commercial, industrial, and park/recreational are respectively occupying 0.77%, 2.4%, 1.7% and 3.8% areas of the selected CBGs. The land use pattern and distribution of different land categories can be visualized from the land use map of the region shown in Figure 5-2. Influence of these land categories on adult asthma patients is described in next section.

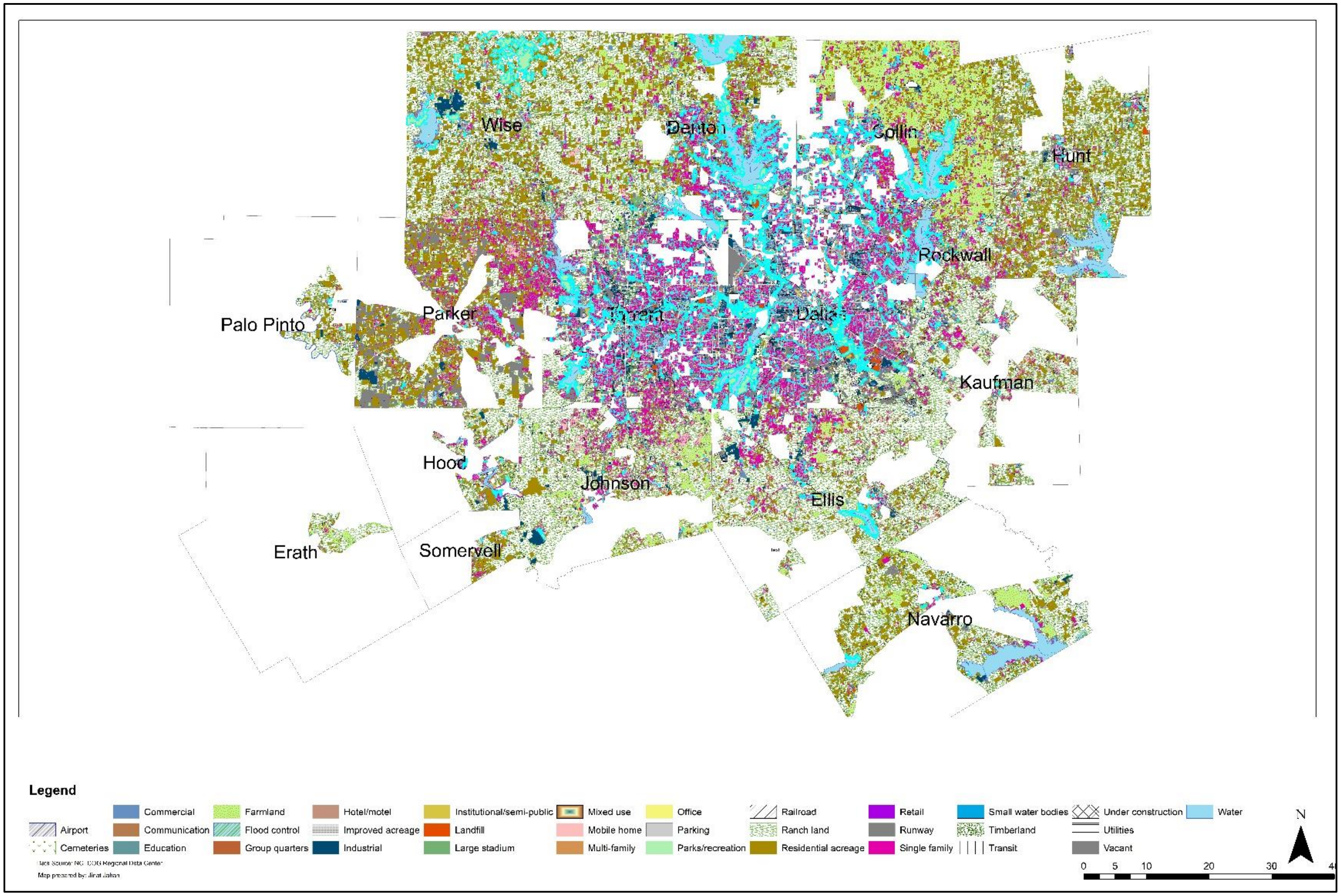

Figure 5-2 Detail land use categories in CBGs with adult asthma hospitalization rates in North Central Texas

5.3 Land Uses and Adult Asthma Hospitalization

This study aims to analyze the influence of different land use categories on adult asthma hospitalization situation. For this, a linear regression model was developed using SPSS 20 where adult asthma hospitalization rate at CBGs is the dependent variable.

Before developing a linear regression model, careful considerations of regression assumptions (such as, linearity, multicollinearity, normality etc.) were made to ensure the best result and relevant measures were took to fix them. For this study, multicollinearity, linearity and normality assumptions have been checked and fixed for developing a regression model.

5.3.1 Check Multicollinearity

To check multicollinearity among the independent variables, a Pearson bivariate multicollinearity analysis was performed for the dependent variable and with all the land use categories (the independent variables). Multicollinearity happens when two explanatory variables are highly correlated. They will generally cancel out each other's effect and create problem to the model (Hoffmann, 2010). If two independent variables are highly correlated to each other, then one of the correlated variables can be excluded from the model. The output table of the correlation model is attached in Appendix. The Pearson Correlation Coefficient for Multifamily and single-family land uses is the highest (-.388) among others. Moreover, multifamily land use has higher colinear coefficient (0.11) with the dependent variable than the single-family land use (0.07). Therefore, excluding one of those variables (single family land use was excluded from farther consideration and considering the multifamily land use in the model). No other independent variables were highly correlated with each other. Therefore, all other categories of land uses except single family residential was considered in the linear regression model.

5.3.2 Check Linearity:

Before running the linear regression model, it is important to know whether there really any linear relationship exists between dependent variable and independent variable. The linearity assumption can be explored with scatter plots which can help to observe the trends (Nau, 2015). In this case, linear relationship has been observed between dependent variable adult asthma hospitalization rate (HospRate) and different independent variables (park/recreational land use and multifamily housing land use). The output scatter graph exhibits there is no pattern or no linear relationship between dependent and any of those independent variables.

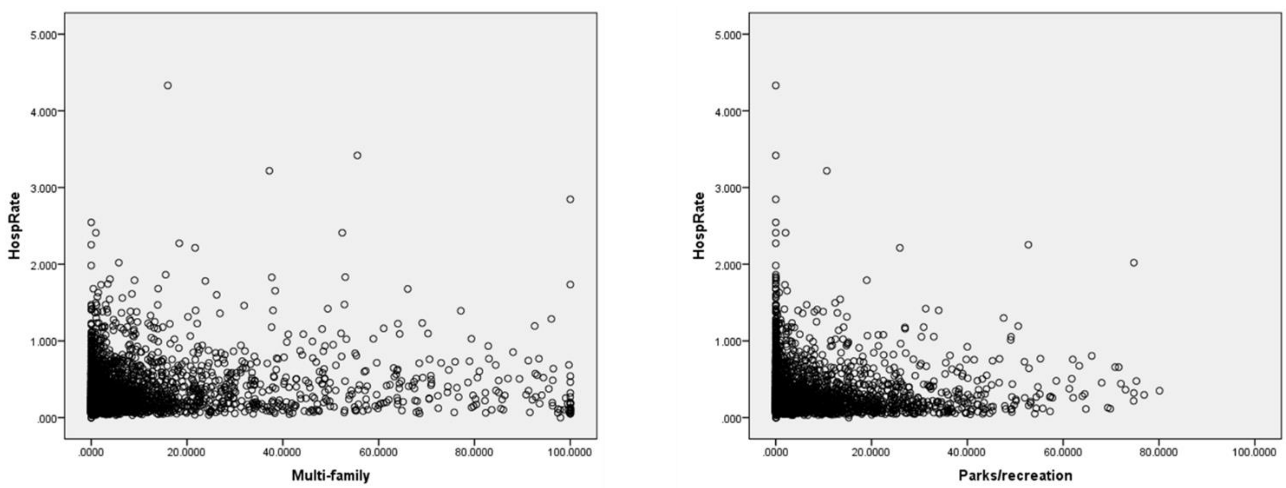

Figure 5-3 Check Linearity between dependent and independent variables

5.3.3 Check Normality

Finally, I checked the normality of dependent variable (Hospitalization rate) by using Histogram diagram. The frequency histogram of adult asthma hospitalization rate (HospRate) and distribution curve indicates that it is skewed (**Figure 5-4**). Violations of normality arises if the distribution of dependent variable is not normal. So, the dependent variable needed some 'fixes' before running the model.

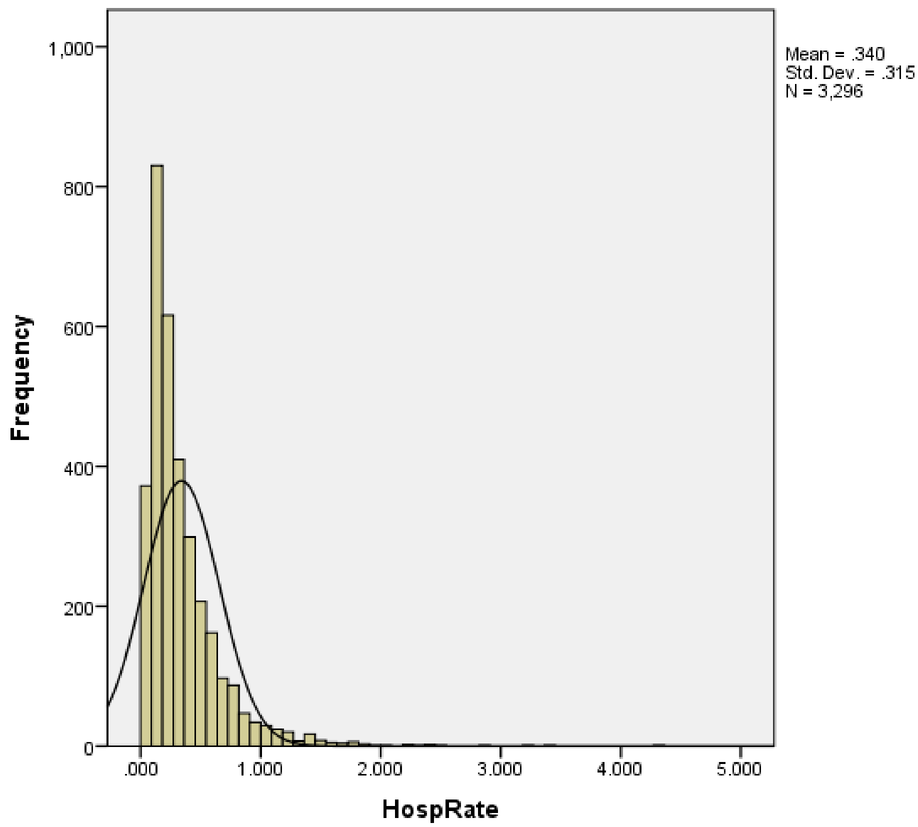

Figure 5-4 Check normality of the dependent variable- adult asthma hospitalization rate (HospRate)

Transformations of data was needed to do to fix non-linearity and non-normality. Generally, the natural log transformation of dependent variable can fix these problems. After log transformation for the dependent variable, it showed a normal distribution curve (Figure 5-5).

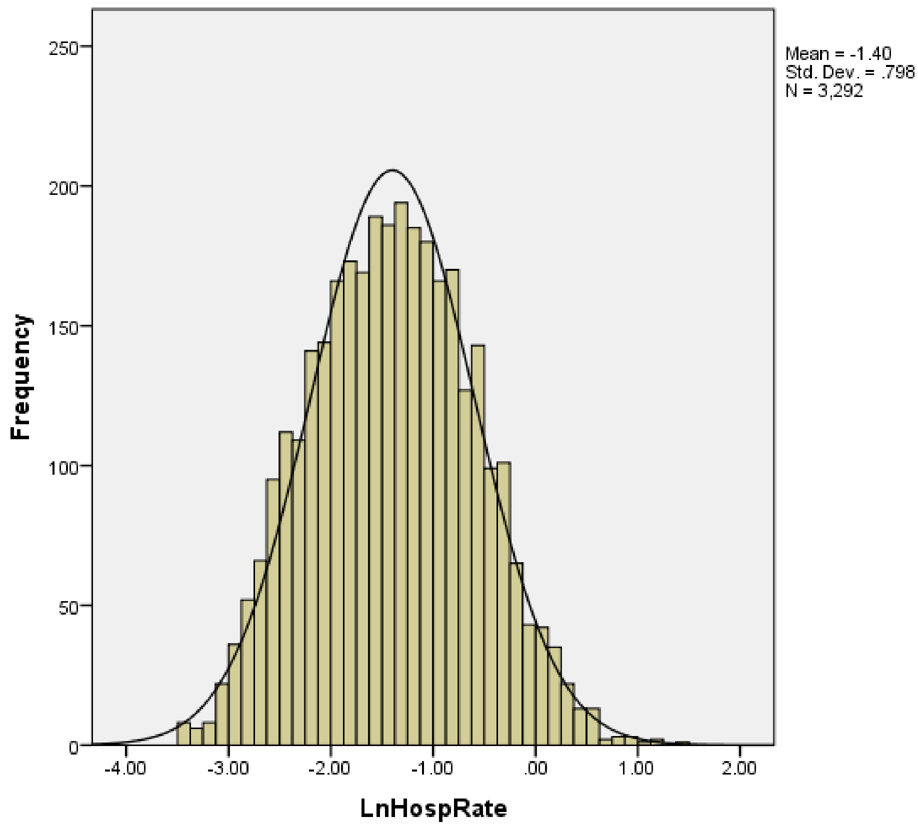

Figure 5-5 Log transformation of dependent variable - adult asthma hospitalization rate (HospRate)

5.3.4 Developing Regression Model

After careful consideration of regression assumptions, a linear regression model was developed using 3296 analyzable Census Block Groups. Proportion of all 33 categories of land uses with respect to the total area of census block groups were considered as independent variable and adult asthma hospitalization rate (log) was considered as the dependent variable. Inclusion of some socio-demographic variables (race, income, education) helped to improve variance of the model. The adjusted R^2 improved from 0.21 to 0.34 after inclusion of socio demographic variables. Thus, the model can explain 34% variance in the target outcome. The model outcome is presented in Table 5-2.

Table 5-2 Influence of all land use categories on adult asthma hospitalization in different Census Block Groups

Variables	Unstandardized Coefficients, B	Std. Error	Standardized Coefficients, Beta	t	significance
Airport (%)	-0.003	0.025	-0.002	-0.117	0.9070
Cemeteries (%)	-0.011	0.005	-0.034	-2.402	0.0160
Commercial (%)	0.001	0.001	0.018	1.12	0.2630
Communication (%)	0.032	0.023	0.02	1.402	0.1610
Education (%)	-0.001	0.002	-0.005	-0.351	0.7260
Farmland (%)	-3.66E-05	0.002	0	-0.02	0.9840
Flood control (%)	0.002	0.004	0.006	0.443	0.6580
Group quarters (%)	-0.029	0.01	-0.044	-3.039	0.0020
Hotel/motel (%)	-0.017	0.012	-0.022	-1.502	0.1330
Improved acreage (%)	-0.001	0.017	-0.001	-0.049	0.9610
Industrial (%)	0.001	0.002	0.008	0.528	0.5970
Institutional (%)	0.002	0.003	0.013	0.866	0.3870
Landfill (%)	-0.001	0.007	-0.001	-0.098	0.9220
Large stadium (%)	0.002	0.012	0.002	0.163	0.8710
Mixed use (%)	-0.035	0.054	-0.009	-0.636	0.5250
Mobile home (%)	0.013	0.003	0.054	3.655	0.0000
Multi-family (%)	0	0.001	-0.004	-0.251	0.8020
Office (%)	-0.011	0.01	-0.015	-1.038	0.2990
Parking (%)	-0.016	0.008	-0.028	-1.935	0.0530
Parks/recreation (%)	0	0.001	0.003	0.2	0.8410
Railroad (%)	0.011	0.006	0.028	1.944	0.0520
Ranch land (%)	0	0.001	0.005	0.303	0.7620
Residential acreage (%)	-0.002	0.002	-0.015	-0.809	0.4180
Retail (%)	-0.004	0.003	-0.023	-1.556	0.1200
Runway (%)	-0.011	0.008	-0.022	-1.271	0.2040
Small water bodies (%)	-0.014	0.014	-0.015	-0.986	0.3240

Timberland (%)	-0.017	0.005	-0.048	-3.244	0.0010
Transit (%)	3.91E-05	0.009	0	0.005	0.9960
Under construction (%)	-0.015	0.013	-0.017	-1.184	0.2360
Utilities (%)	0.003	0.005	0.008	0.578	0.5640
Vacant (%)	0.006	0.001	0.081	5.247	0.0000
Water (%)	0.001	0.001	0.006	0.435	0.6630
Median Household Income	-7.31E-06	0	-0.29	-15.771	0.0000
Population aged 25 and over without a high school diploma	0.001	0.001	0.033	2.124	0.0340
RACE: White	0	0	-0.294	-16.963	0.0000
RACE: Black or African American	0	0	0.133	8.502	0.0000
RACE: American Indian and Alaska Native	2.24E-06	0	0	0.005	0.9960
RACE: Asian	-0.001	0	-0.136	-8.721	0.0000
RACE: Native Hawaiian and Other Pacific Islander	0.001	0.001	0.017	1.157	0.2480
RACE: Some other race	0	0	-0.086	-5.588	0.0000

Dependent variable: Adult Asthma Hospitalization Rate (log)
Adjusted R^2: 0.340

Only 13 independent variables out of 40 variables are significant ($p < 0.10$) in the first model. After controlling for age and gender, a final model was developed contained variables that achieved significance ($p < 0.10$). Though industrial, commercial, park/recreational and residential land uses (multifamily) are not significant in the first model but I considered these land uses in the final model since these variables were found important in asthma related studies (Ebisu et al., 2011; Rao et al., 2017, Maantay, 2001).

The adjusted R^2 of the final model is 0.341, thus this model can explain 34% variance of the data, which is same as the first model. The result of final regression model output for the land use category and adult asthma hospitalization is presented in Table 5-3.

Table 5-3 Influence of statistically significant and other important land uses on adult asthma hospitalization rate

Variables	Unstandardized Coefficients, B	Std. Error	Standardized Coefficients, Beta	t	significance
Cemeteries (%)	-.0108	0.004	-0.034	-2.393	0.017
Group quarters (%)	-.0300	0.01	-0.045	-3.136	0.002
Industrial (%)	.0012	0.002	0.008	0.561	0.575
Mobile home (%)	.0124	0.003	0.053	3.618	0
Parking (%)	-.0162	0.008	-0.029	-2.003	0.045
Railroad (%)	.0120	0.006	0.03	2.089	0.037
Timberland (%)	-.0173	0.005	-0.049	-3.398	0.001
Vacant (%)	.0060	0.001	0.079	5.201	0
Commercial (%)	.0009	0.001	0.012	0.784	0.433
Parks/recreation (%)	.0002	0.001	0.003	0.172	0.864
Multi-family (%)	-.0004	0.001	-0.009	-0.566	0.571
Median Household Income	-7.40E-06	0	-0.293	-16.361	0
Population aged 25 and over without a high school diploma	.0011	0.001	0.034	2.201	0.028
RACE: White	-.0003	0	-0.296	-18.053	0
RACE: Black or African American	.0003	0	0.135	8.773	0
RACE: Asian	-.0006	0	-0.135	-8.81	0
RACE: Some other race	-.0003	0	-0.085	-5.581	0

Dependent variable: Adult Asthma Hospitalization Rate (log)
Adjusted R^2: 0.341

5.3.5 Findings from the model

The output of the model provides some interesting findings for land uses and their influence on adult asthma condition in north central Texas region. Different land uses in census block groups where adult asthma patients reside found to have different association.

Cemeteries are maintained as the green spaces and preserved with peace and tranquility. Presence of burial sites in census block groups thus found to have negative relationship with adult asthma condition. Increased proportion of cemeteries that are maintained as green spaces found to have reduced adult asthma hospitalization rate in respective census block groups. In the land use categories of NCTCOG, “Timberland” is solely natural green space that contains wood, or the land is covered by trees. For this category of land, it is obvious that, with the increase of such green spaces the adult asthma hospitalization reduces. This land category is significant in the model ($p < 0.10$). With 1 percent increase of timberland in the per square mile area of CBGs would help to reduce 0.0173 unit or 1.73 percent adult asthma hospitalization in the area. Preservation of such natural wood or green spaces in any area can help to reduce any respiratory problems among the residents (Ebisu et al. 2011).

In case of residential land uses, it is found from the output table that, presence of group quarters (nursing homes, college dormitories etc.) in a CBG is negatively associated with adult asthma hospitalization. Increase of group quarters can decrease the adult asthma hospitalization rate in a CBG. Group quarters like nursing homes can help managing asthma of their residents at home. This can help to reduce hospital admission as it is assumed that hospitalization of adult asthma patients is due to lack of access to proper medication when needed (Newcomb P. and J. Li 2019b).

On the other hand, mobile home is positively associated with adult asthma hospitalization. Such findings comply with previous literature. According to investigation of previous studies, mobile homes are built with materials that might release formaldehyde and chronic inhalation of such chemical can contribute to the exacerbated respiratory condition (Gan, W. Q., Sanderson, W. T., Browning, S. R., & Mannino 2017). Similarly, multifamily housing is positively associated with adult asthma exacerbation. The reason behind their positive association with asthma exacerbation can be understood as multifamily structures pose indoor air quality (IAQ) challenges because air pollutants may transfer from one unit to another and residents have limited ability to improve the situation by making any changes to the building (US EPA - United States Environmental Protection Agengy 2018).

Results of my study also indicate that, increased parking spaces in neighborhood is strongly associated with reduced asthma hospitalization rate. This is may be due the neighborhood lands are occupied with more parking lots and less land is remained for residential uses where asthma people could live. Moreover, large parking lots are found with commercial, industrial or administrative uses. Therefore, it does not mean parking lots helped to reduce asthma exacerbation and urban planners, policy makers would not be encouraged to have increased parking lots in any area.

One important finding from the analysis is that neighborhoods with railroads are strongly associated to have increased asthma hospitalization rate. One percent increase of railroad areas in the CBGs is related to 1.62 percent increase of adult asthma hospitalization. Previous studies have also found railroads to be responsible for asthma exacerbation specially for asthmatic children since such land uses generate traffic related air pollutions (Juhn et al. 2010). Results of my study found that, such land use is also detrimental for adults with asthma.

Among different land uses, previous literature considered the commercial and industrial as important land use factors that can have influence on asthma exacerbation (Maantay 2001). Though, these land uses are statistically insignificant in this research model, but direction of their association complies with previous scholarly findings. In this region, increased proportion of commercial land use in CBGs exacerbate asthma condition. Literature suggests that, commercial areas may emit air pollutants due to commercial uses and those areas are characterized by factors such as less vegetation that minimizes air pollution. Similarly, the negative impact of industrial land use on asthma condition is widely known. Like other areas, CBGs in north central Texas experience higher adult asthma hospitalization with the increased amount of industrial land uses. Because, industrial sites can provoke local air pollution that can be threat for people with asthma (Pala et al. 2019).

One of the interesting findings from the research model is that CBGs with vacant lands have higher adult asthma hospitalization rate. According to NCTCOG, vacant lands are undeveloped land lying in between other categories of land uses (Figure 5-1 and Figure 5-11).The Urban Institute considers vacant land as part of urban blight and refers as neglected and empty parcels of land in a neighborhood (De Leon, E., & Schilling 2017). Researchers have long studied the negative impact of vacant land/lot on public health and safety. Vacant land was described as impacting health through creating unhealthy environment such as buildup of trash (Branas et al. 2011). A study on Detroit identified that plants grew on vacant land created pollen problem and have potential for asthma exacerbation (Brazeal 2019). Thus, vacant lots can be threat for safety and health (De Leon, E., & Schilling 2017). The urban areas of north central Texas are dotted with vacant lands. Findings of my research indicate that they pose risk of respiratory health hazard. With the increase of vacant lots in CBGs the adult asthma hospitalization also increases.

To better understand the overall relation between asthma and land use, a spatial assessment using hotspot analysis was conducted. Discussion about the spatial analysis of asthma exacerbation and land use is in the next section.

5.4 Spatial Cluster Analysis of adult asthma hospitalization and land uses

A spatial cluster analysis can provide a visual representation and can help to better understand the land use and adult asthma situation. For this, the information of Census Block Groups with adult asthma hospitalization rates were entered into a Geographic Information System using Arcview software. In order to be a statistically significant hot spot, a feature need to have a high value and be surrounded by other features with high values as well (Environmental Systems Research Institute (ESRI), n.d.). I used the Hot Spot Analysis (Getis-Ord Gi*) tool to determine the location of CBG hotspots or clusters with elevated asthma hospitalization rate for adult above 18 years old.

The hotspots of Census Block Groups were defined as where the adult asthma hospitalization rates are high, and z-scores are statistically significant positive. The larger the z-score is the more intense the clustering of high values (hot spot). For cold spot, the z-scores are statistically significant negative and the smaller the z-score is, the more intense the clustering of low values (Environmental Systems Research Institute (ESRI), n.d.). The hotspots in this research was defined as contiguous census block groups where the observed adult asthma hospitalization rate was high with 90%, 95% and 99% confidence interval. The hotspots for adult asthma hospitalization are shown in Figure 5-7. The hotspots are geographically clustered mainly into three locations and I named those hotspots with name of the

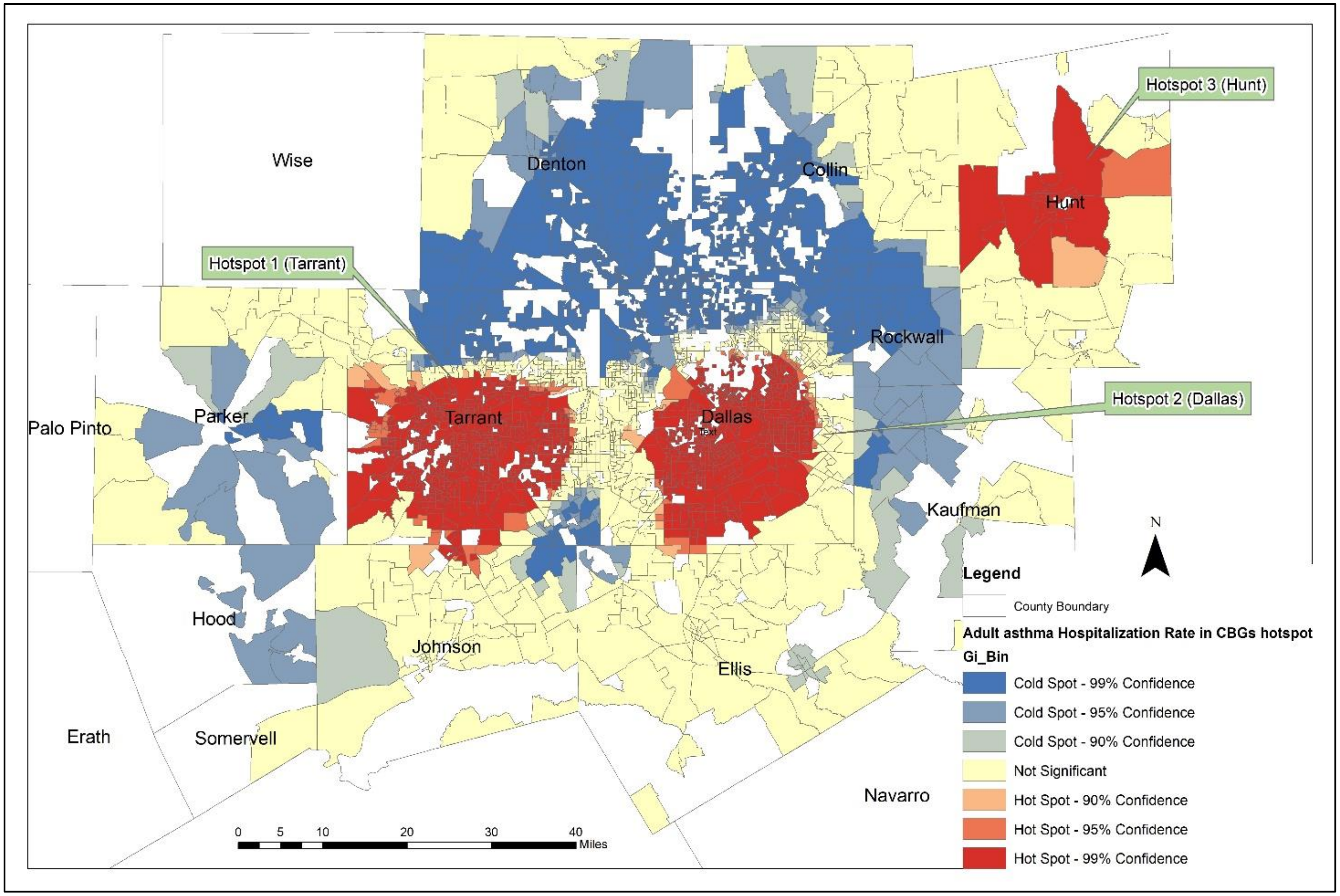

Figure 5-6 Hotspots of adult asthma hospitalization rate in north central Texas region

county where they are located. They are: Hotspot 1(Tarrant), Hotspot 2 (Dallas) and Hotspot 3 (Hunt). Out of 3246 CBGs with adult asthma patients, 1347 CBGs are in those hotspots. About 36% of total adult population of all those CBGs with adult asthma patients are living in those three hotspots. About 50% of adult asthma patients (5713 out of 11519 unduplicated patients) are living in those hotspot census block groups.

The land use pattern in those hotspots can be visible from the detail land use maps of those three locations (Figure 5-7 to 5-9). All three hotspots are located at the core of the respective counties. It is evident from the hotspot maps of Tarrant (Figure 5-7) and Dallas (Figure 5-8) county that, those clusters are complex hub of single family residential, vacant lots, commercial, communication, railroad, institutional and industrial land uses. On the other hand, for the Hotspot 3 (Hunt) (Figure 5-9), vacant lot is one of the prominent land categories in those neighborhoods. It has already been found from regression model output and discussed in previous section that; these land uses (vacant lots) have positive association with asthma exacerbation in the region.

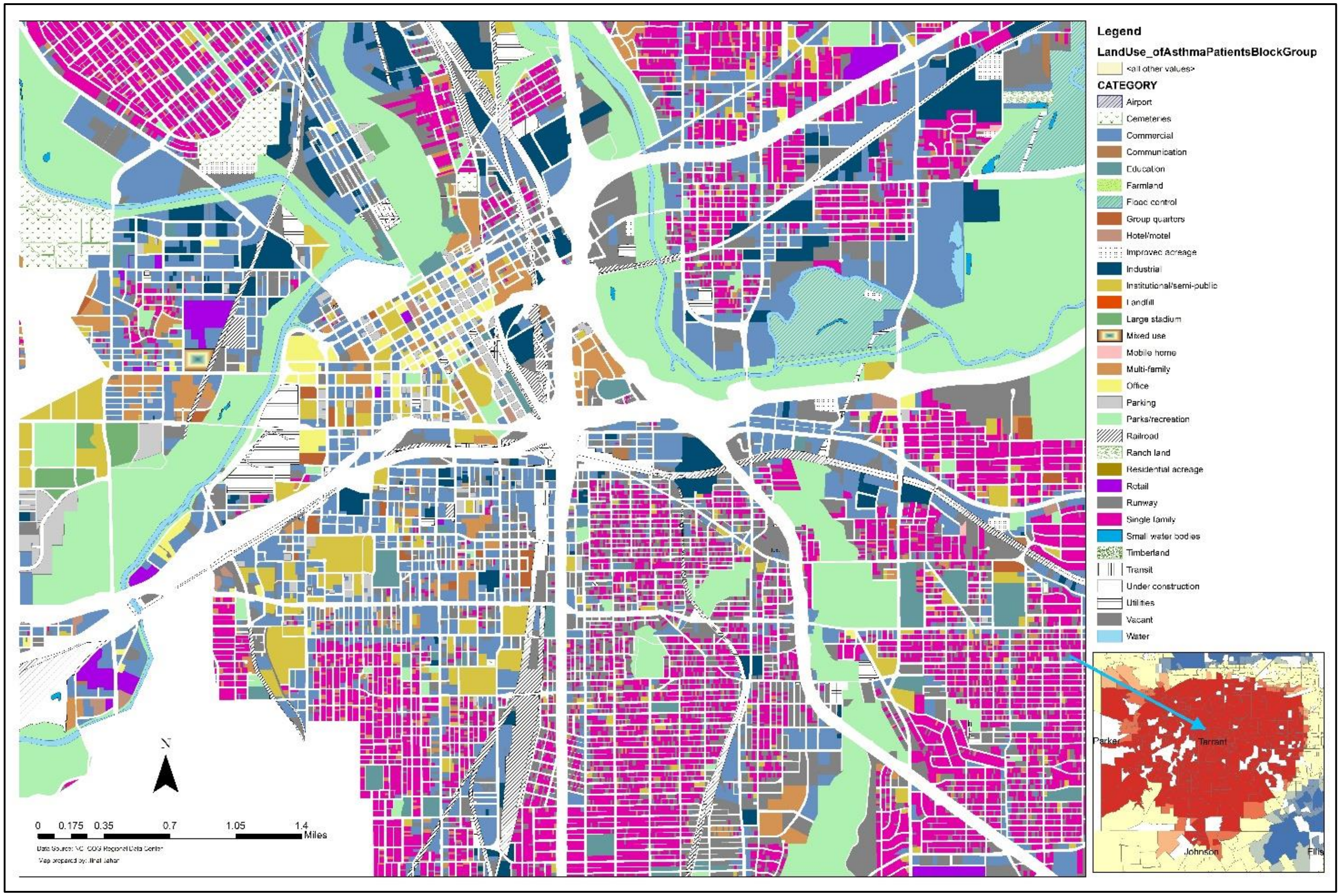

Figure 5-7 Land uses in Hotspot 1(Tarrant)

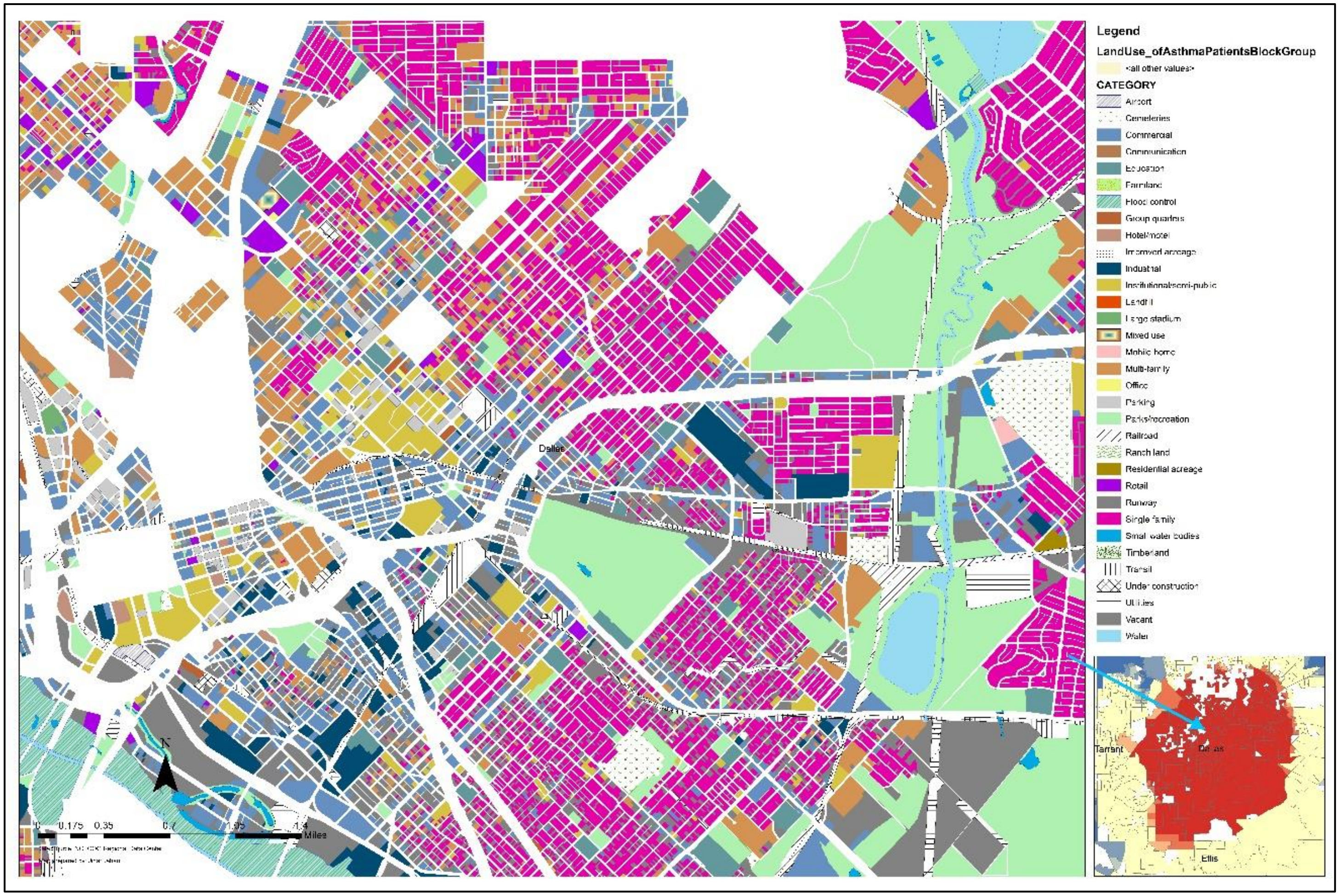

Figure 5-8 Land uses in Hotspot 2 (Dallas)

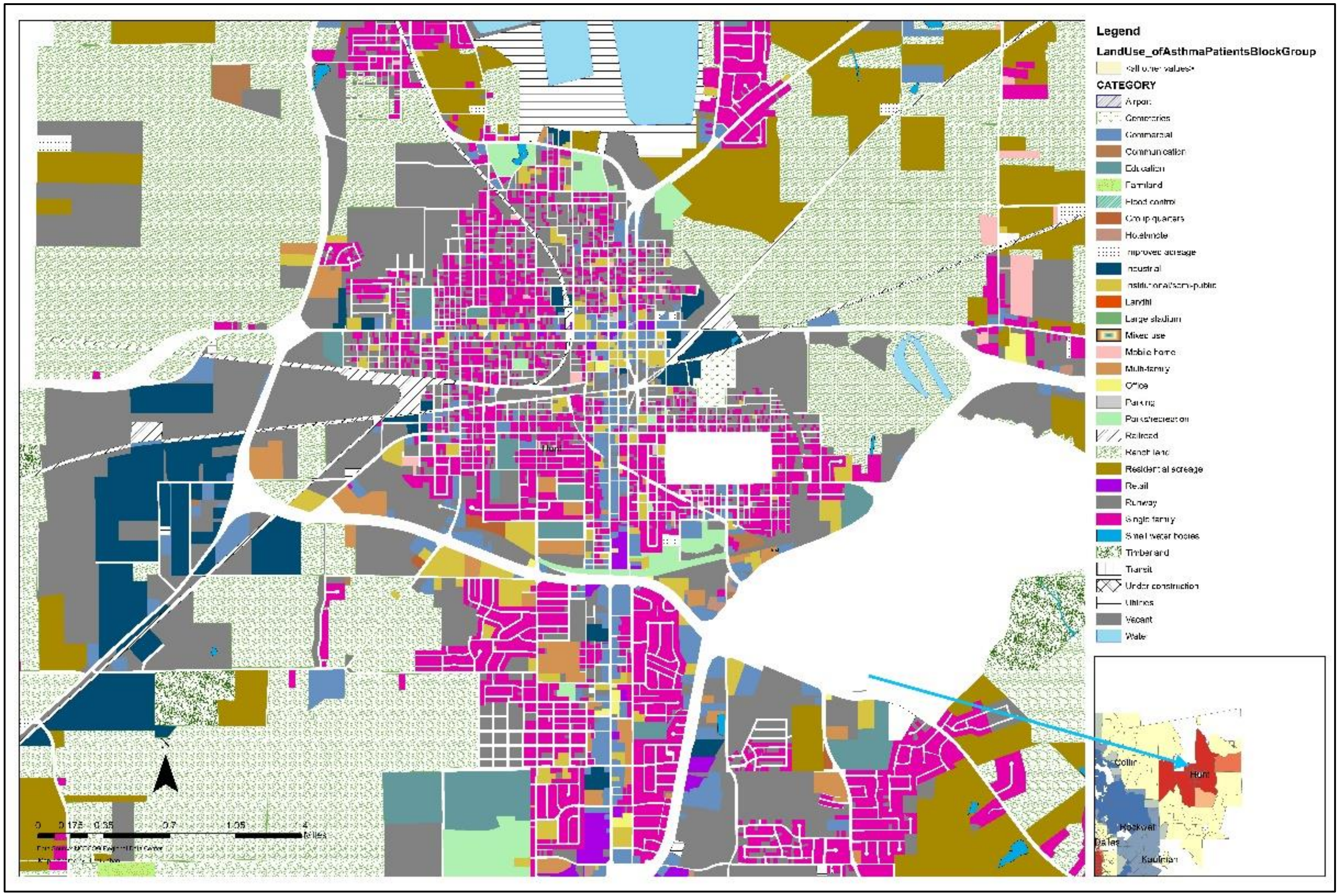

Figure 5-9 Land uses in Hotspot 3 (Hunt).

Apart from the land use aspects, the socio demographic output from the model indicates that, with the increase of median household income in census block group the adult asthma hospitalization rate decreases. In Figure 5-10, a spatial analysis using income and hotspots of hospitalization reveal that the results are remarkably similar. In the Figure 5-10 it is evident that, the hotspot areas like cores of Dallas, Tarrant or Hunt county have low to moderate income levels. The census block groups with high median income are cold spot in the adult asthma hospitalization hotspot map. Such visualization helped to understand the inverse relationship between income and adult asthma hospitalization rate. Moreover, the null hypothesis "with the increase of income the adult asthma hospitalization decrease" gets rejected.

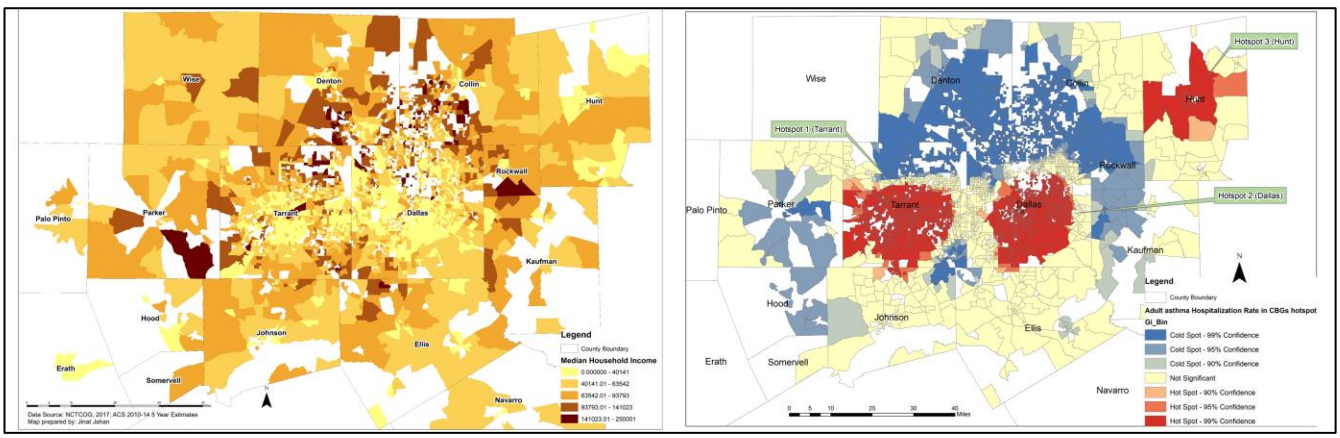

Figure 5-10(a) Median Household income in CBGs; (b) hotspots of adult asthma hospitalization rate

On the other hand, asthma hospitalization had positive relationship with low education level. With the increase of people with lower education (Population aged 25 and over without a high school diploma) the hospitalization rate due to asthma severity among adults increases in the CBGs. The null hypothesis "with the increase of education at census block group level, the adult asthma hospitalization rate decreases" gets rejected.

Adult asthma hospitalization increases in CBGs that have higher number of black population but decreases with the increase white population and with people of Asian origin. Such result of socio demographic variable indicates severe health discrepancies existed at neighborhood level.

5.5 Summary

To the best of my knowledge, this research is one of the very first attempts to investigate detail land use categories and their influence on adult asthma in north central Texas region. The relationship between land uses and respiratory health is a complex phenomenon. Though land use may have some degree of influence on asthma severity but there might be several underlying factors such as genetic factors, lifestyle, food habits and so on, which have not been investigated in this research. However, the hypothesis of the research is that, adult asthma hospitalization rate reduces in census block groups where proportion of green spaces are high. As the model output indicates that, increased presence of wood/trees/uninterrupted green space (namely Timberland) in neighborhood can help reducing asthma severity in terms of reduced hospitalization rate of adult asthma patients, therefore, the null-hypothesis of the research gets rejected.

Besides, there are some interesting incidental findings from the model output. Vacant lands are found to be detrimental for social and health aspects in many other regions (Garvin, E., Branas, C., Keddem, S., Sellman, J., & Cannuscio 2013; De Leon, E., & Schilling 2017; Branas et al. 2011). Such land use is also found to trigger asthma exacerbation in north central Texas region. By exploring such interesting aspects, this research provides scope for more detail analysis on individual land use types, their current condition and influence on asthma condition in this region.

Chapter 6 Adult asthma hospitalization and transportation variables

6.1 Introduction

Different literature indicated that, transportation systems have influence on asthma severity. Traffic related air pollution is considered as one of the main factors for asthma exacerbation. In my research, I used different transportation variables as proxy to measure the exposure to traffic related pollution and their influence on adult asthma hospitalization. This chapter focuses on the aspects of adult asthma hospitalization that can be influenced by traffic exposure.

6.2 Measures of Traffic Exposure

In my research, I considered travel time to work, weighted average speed in CBGs, weighted road density in each census block groups and proximity to major roads as proxy variables to measure exposure to traffic related air pollution.

6.2.1 Travel Time to work

This study is one of the first attempts to investigate the association between travel time and adult asthma condition in the US. As I considered adult population, therefore travel time to work was considered mainly and did not consider any travel with other purposes (like grocery, entertainment, etc.). The data I considered in my research is “Travel Time to Work: Total: Workers 16 years and over who did not work at home” available from the American Community Survey (ACS) 5-year estimates 2010-14 for census block group level.

6.2.2 Weighted Road Density

In this research, I considered the hierarchy of roads in terms of weighted road density. Consideration of weighted road density can capture the cumulative road exposure of different types of roads located nearby (Hansell et al. 2014). The number of traffic lane, traffic volume, speed and purposes are different for different road types. The weighted road density was considered for the internal roads within the CBGs ranging from major highways, arterials to private roads of a property. In this research, I considered the road data available from NCTCOG's Regional Data Center. It is available in the form of GIS shapefile. This dataset includes road centerlines for all 16 counties in the NCTCOG region. This layer was developed based on information from various sources including Regional 9-1-1 Program for Collin, Ellis, Erath, Hood, Hunt, Johnson, Kaufman, Navarro, Palo Pinto, Parker, Rockwall, Somervell, Dallas and Wise counties, Denton County, City of Dallas and Tarrant 911 (NCTCOG Regional Data Center 2020).

Their inventory includes 11 different types of roads: primary highway, secondary highway, major arterial, minor arterial, access ramp, service road, connecting road, private road, driveway, trail (unpaved pathways for nonmotorized vehicles like cycling or for pedestrian) and other (unspecified) categories. In my model, I did not consider trail and "other" category of roads. To determine the weightage for different road types, I have considered the following rule found in the manual of Texas Department of Transportation (TxDOT).

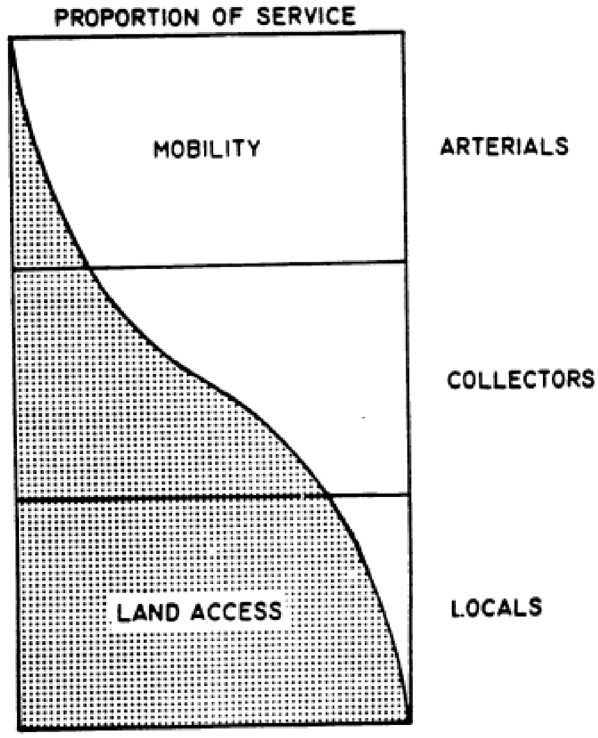

Figure 6-1 Hierarchy of roads in terms of mobility and land access (TxDOT, Online Manual, page 9)

Hansell et al (2018) considered weighted sum of the lengths of road within 50 meters radius of geocoded residential addresses of children (5 and 8 years) who have allergic disease and lung function (asthma, wheezing). Within that 50 meters radius, the arterial roads were given a weighting of 3, distributor roads had weighting of 2 and local roads given a weighting of 1. Similar to the study of Hansell et al (2018), I considered following weightage for different road types depending on their mobility and access to property. As access ramps connect the traffic with highways and service road runs in parallel with highways, therefore I assumed similar weightage for both road categories. Similarly, driveway and Private roads are internal road of a property therefore I gave them similar weightage value.

Table 6-1 Weightage value for different road types in the hierarchy

Road type	Weightage value
Driveway	1
Private Road	1
Connecting Road	2
Minor Arterial	3
Major Arterial	4
Access Ramp	5
Service Road	5
Freeways/Major Highways	6

After providing the weightage value, I calculated the Weighted Road Density with the following equation:

Weighted Road Density= [Driveway length (mile)*1 + Private Road Length (mile)*1 + Connecting Road (mile)*2 + Minor Arterial (mile)*3 + Major Arterial (mile)*4 + Access Ramp (mile)*5 + Service Road (mile)*5+major highways(mile)*6] in a CBG/ Area of pertinent CBG (Square mile)

This variable would reflect the amount of road (length) in per square mile area of any census block group.

6.2.3 Weighted Average Speed

In a similar way to the weighted road density, the weighted average speed of traffic in a census block group was considered. The average speed for different road types was found from the road shapefile of NCTCOG's Regional Data Center. Though the average speed of each category I calculated was in decimal value, but I rounded up to the nearest value of any speed limit that exists in the transportation network system. For example, the mean speed of all the connecting roads in the region calculated was 27.34 mile per hour (mph) and I considered it 30 mph as this speed limit exists in the actual traffic network system. The average speed considered for different road types are as follow:

Table 6-2 Considering average road speed for different road types in the hierarchy

Road type	**Average Speed (mph) considered**
Private Road	20
Driveway	25
Connecting Road	30
Minor Arterial	35
Major Arterial	55
Access Ramp	60
Service Road	60
Freeways/Major Highways	75

The weighted average speed (mph) for census block groups was calculated using following equation:

Weighted average speed= [Private Road Length (mile)*20 mph +Driveway length (mile)* 25 mph + Connecting Road (mile)* 30 mph + Minor Arterial (mile)* 35 mph + Major Arterial (mile)* 55 mph + Access Ramp (mile)* 60 mph + Service Road (mile)* 60 mph+ major highways (mile)* 75 mph] in a CBG/ Total length (mile) of all types of road in pertinent CBG

The weighted average speed indicates the average speed at which vehicles are running in per mile of road length in pertinent Census Block Groups.

6.2.4 Proximity to major roads

A growing number of research suggest that residential proximity to traffic sources increase the risk for development of asthma (McConnel et al, 2006). Moreover, different studies consider different distances. For example, Huynh et al. (2010) considered 2 miles of distance as the measure of proximity to freeways to investigate the condition of asthma patients in Los Angeles, CA, on the other hand, Li et al (2011) considered up to 500 meters of primary roads of Detroit, MI in order to investigate acute asthma cases.

However, two significant studies were found on north Texas region that considered distance from major roads as a measure of transportation exposure and their possible impact on asthma patients. One of those studies considered 1500 meters distance to major roadways from residence of asthma patients and their logistic regression model showed distance to a major road from the patient's residence had strong predictive effect (Newcomb and Li, 2008). On the other hand, the same authors in another research, considered census block groups within 500 ft buffer zone of major roadways but effect of this variable (500 ft from major highway) was not statistically significant at 0.05 level hence the study found no significant differences in measures of this transportation exposure. Some studies considered the proximity to roads as ordinal or categorical variables (Hansell et al, 2014; Franklin et al, 2012). These studies considered the categories for proximity to road based on prior empirical evidence regarding dispersion of traffic related air pollutants (WHO regional office for Europe, 2013) and related available literature. Hansell et al (2014) considered three categories of proximity: closer than 75 m (high exposure), between 75 and 500 m (medium exposure), and 500 m or more (low exposure) regardless of road categories for targeted community. On the other hand, Franklin et al (2012) considered different ranges of proximity for freeways and non-freeways. For freeway, they considered ranges of <250 m, 250–500 m, 500–1,500 m, and >1,500 m and <75 m, 75–150 m, 150–300 m, and >300 m for distance to non-freeway roads for thirteen southern California communities.

In this research, as I considered distance of CBGs from major highways or freeways, therefore, I considered almost similar range mentioned by Franklin et al (2012) as follow: census block groups within 0.25 mile (very high exposure), 0.5 mile (high exposure), and within 1 mile (low exposure) of primary and secondary highways. The information of primary and secondary highway is available in road dataset from NCTCOG's Regional Data Center discussed above. If any CBG of the study area is located within 2 different ranges, for example, if any CBG has some portion of their area within the range of quarter mile (0.25 mile) and some other portion within the range of half mile (0.5 mile) of distance, to avoid such cases, I considered the centroid of the CBGs to measure the distance from those highways. I created quarter mile, half mile and one-mile buffer around primary and secondary highways in GIS to consider those distances. Figure 6-2 depicts different ranges of buffer around primary and secondary highways.

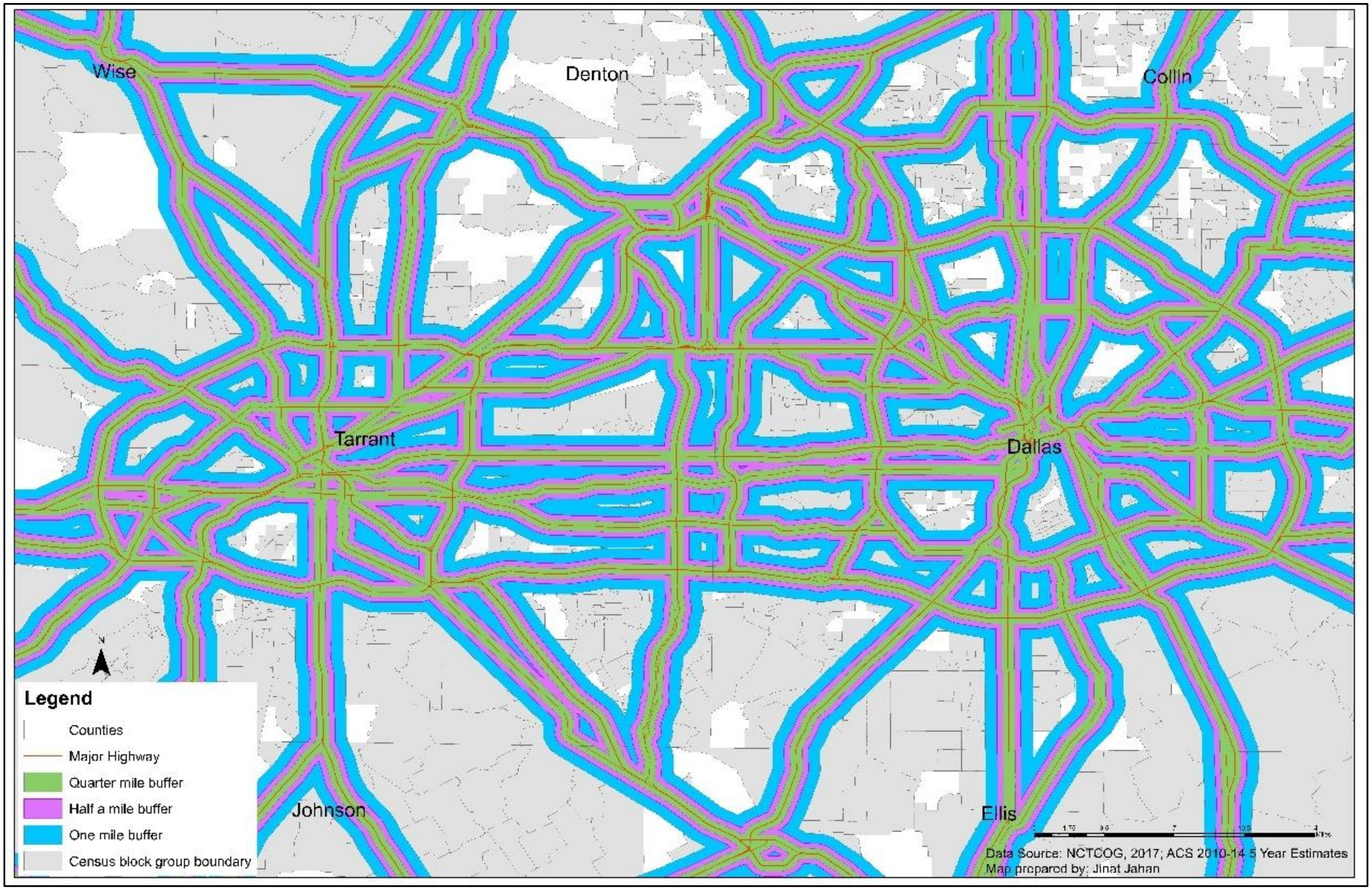

Figure 6-2 Quarter mile, half a mile and one mile buffer around major highways.

For all the three buffer ranges, the census block groups that have their centroid within the buffer were coded as 1 and 0 otherwise.

6.3 Adult asthma hospitalization rate and transportation variables

This study aims to analyze the impact of traffic exposures on adult asthma hospitalization situation. For this, a linear regression model was developed to observe the influence of several traffic exposure variables on adult asthma hospitalization rate.

Before developing a model, careful considerations of regression assumptions (such as, linearity, multicollinearity, normality etc.) were made to ensure the best result and relevant measures were took to fix them. As linearity and normality of the dependent variable was already checked, therefore, for this section, only multicollinearity among independent variables was investigated. The transportation variables considered in the model were proximity to major highways, travel time to work, weighted road density, and weighted average speed in CBGs. A Pearson bivariate correlation was developed for all the transportation variables. The output table of the model is in appendix.

From the output of the Pearson Correlation model it was evident that, the variable for “census block group within 0.25 mile buffer” was moderately correlated to the variables for “census block group within 0.5 mile buffer” (correlation coefficient 0.561) and “census block group within 1 mile buffer” (correlation coefficient 0.571). To avoid multicollinearity among these variables, “census block groups within 0.25 mile buffer” was excluded from farther consideration. Other independent variables were not strongly correlated among themselves.

Besides the transportation variables, incorporation of socio-demographic variables that are highly correlated with the dependent variable were also considered (same social indicators that were used in linear regression model for land use categories and adult asthma hospitalization rate). This helped the model to improve the adjusted R^2 from 0.14 to 0.31. This indicates, the model can explain 31% variance of the data. The result of linear regression model for the transportation variables and adult asthma hospitalization is presented in Table 6-3.

Table 6-3 Influence of traffic exposure on adult asthma hospitalization rate

Variables	Unstandardized Coefficients, B	Std. Error	Standardized Coefficients, Beta	t	significance
Median Household Income	-7.2E-06	5E-07	-0.2711	-14.4978	0.000
Population aged 25 and over without a high school diploma	0.001042	0.000577	0.030796	1.805349	0.071
RACE: White	-0.00014	3.83E-05	-0.13213	-3.68849	0.000
RACE: Black or African American	0.000433	4.2E-05	0.223855	10.3005	0.000
RACE: Asian	-0.00036	8.63E-05	-0.08114	-4.16191	0.000
RACE: Some other race	-0.00022	7.41E-05	-0.0531	-2.93808	0.003
Weighted Road Density	0.000468	0.000444	0.019094	1.054926	0.292
Weighted Average Speed	0.000957	0.002359	0.007117	0.405819	0.685
Total Travel Time to Work: Workers 16 years and over who did not work at home	-0.00036	7.07E-05	-0.2033	-5.04379	0.000
CBGs have their centroid within 0.5 mile of major highways (high proximity)	0.030743	0.030754	0.019352	0.999646	0.318
CBGs have their centroid within 1 mile of major highways (low proximity)	-0.01545	0.037884	-0.00751	-0.40769	0.684

Dependent variable: Adult Asthma Hospitalization Rate (log)
Adjusted R2: 0.31

Among five transportation variables in the model, only one variable “total travel time to work” is statistically significant ($p < 0.10$). Output of the model indicates that, there is strong association between travel time to work (or commuting time) with adult asthma hospitalization in CBGs. Also, this variable (travel time to work) has unexpected direction of sign than other transportation variables.

According to the model output, the CBGs where it takes longer time to travel for work, there are reduced rate of adult asthma hospitalization. This is an interesting finding for the auto oriented north central Texas region. As it was assumed that higher commuting time indicates exposure to traffic pollution for longer period which can affect the asthma condition, therefore with the increased total travel time in CBGs the adult asthma hospitalization would also increase. But the model output is indicating a different scenario. One possible reason can be that; adults who have severe asthma may be aware of their condition and avoid longer traffic exposure time and choose to live close to their workplace as a precaution of their health condition. Such inverse relationship between total travel time to work and adult asthma hospitalization rate in CBGs can be logically realized by comparing Figure 6-3 (a) (CBG Travel Time Map) and Figure 6-3 (b) (Hotspots of adult asthma hospitalization rate). In the travel time map, green indicates less time to travel for work and red indicates higher commuting time. It is visible/understandable by comparing the two maps that, the core areas of Dallas, Tarrant and Hunt county where the hotspots are located are green in the travel time map, indicating total travel time to work for workers is very low in those places. On the other hand, the areas that are red (very high travel time to work in Figure 6-3 (a) "Travel time to work") are actually cold spots in the Figure 6-3 (b) (Hotspot map). Therefore, the null hypothesis of the research, "adult asthma hospitalization rate increases in CBGs where travel time to work is high" is failed to reject.

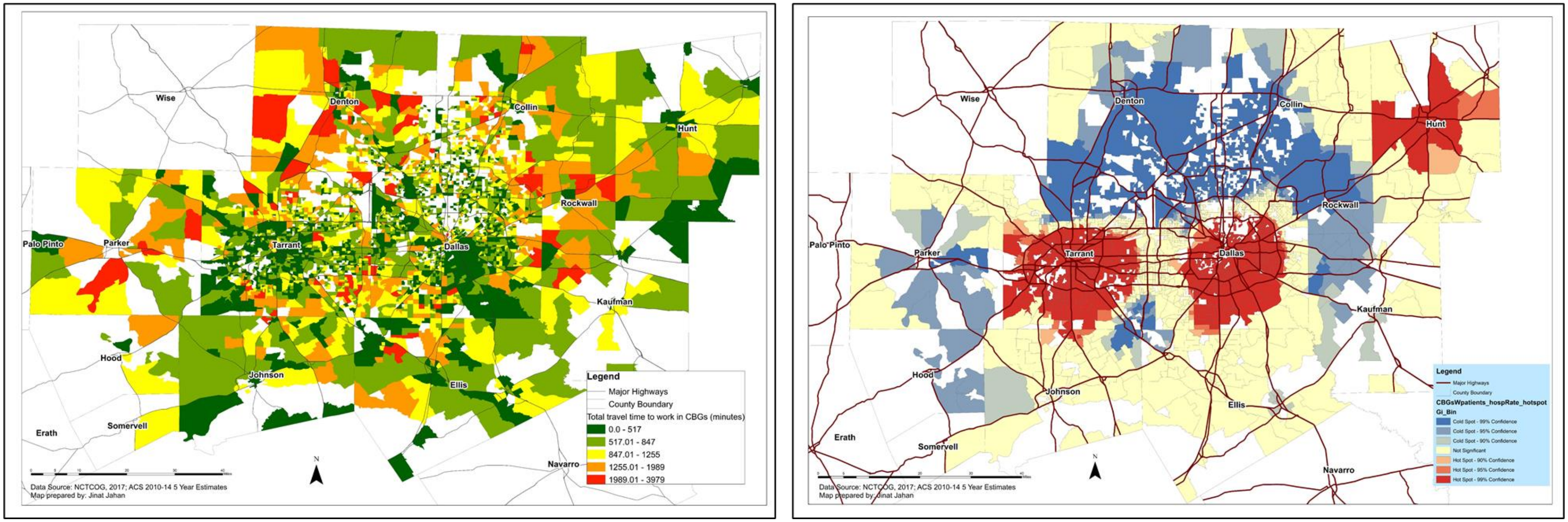

Figure 6-3 (a) Total travel time to work for workers living in different CBGs (b) Spatial cluster or Hotspots of adult asthma hospitalization rate and major highways in north central Texas region.

Other traffic exposure variables have expected sign of coefficient though they are not significant in the model ($p > 0.10$). According to previous literature, increased amount of traffic infrastructure in a neighborhood is responsible for increased exacerbation of respiratory system (Hansell et al. 2014; Rose et al. 2009). Output of my research model for the variable 'weighted road density' comply with previous findings. The finding indicates increased amount of road infrastructure in surrounding built environment is associated with increased adult asthma hospitalization rate in north central Texas. The model output reflects that, increase road density that is indicating increased traffic activity is related to increased asthma exacerbation.

Similarly, for average speed of traffic in road, increased average speed in an area was assumed to indicate increased activity of traffic hence have influence on asthma severity. The coefficient for the weighted average speed of traffic on the roads of CBGs indicate traffic moving in higher speed inside the area is weakly associated with high adult asthma hospitalization rate.

In addition to these variables, variables for proximity to major roads in the model output indicate that with increased distance from major highway the adult asthma hospitalization rate decreases. The direction of relation indicates that, adult asthma hospitalization rate is high in those CBGs that have their centroid within 0.5 mile of major highways (high proximity). But the hospitalization rate decreases with the increased distance from the major highways as it can be seen from the output that with low proximity (CBGs that have their centroid within 1 mile of major highways) the rate for hospital visit decrease. Moreover, this context can be visualized and easily understood from Figure 6-2 buffer and Figure 6-3(b). It can be seen from Figure 6-3 (b), that the hotspots are intersected by many major highways like I-30, I-20, I-35, etc. and busy traffic on highways can create nuisance in nearby areas.

Besides the transportation variables, the socio-economic variables have impact on asthma hospitalization, which has already discussed in previous sections.

6.4 Summary

The association between transportation and asthma exacerbation has long been studied. Different studies found different degrees of impact of various transportation variables on asthma situation as well as on other respiratory conditions (Lin et al. 2002; Morgenstern et al. 2008). One of the previous studies about north central Texas also focused on road density and impact on childhood asthma. But that study had limitation as the researchers were not able to consider road type and number of lanes, as road function, traffic volume, and travel speed do affect vehicle emission. That study found with the increase of road density the asthma severity decreases (Li and Newcomb, 2009). In my research, consideration of road hierarchy in terms of mobility and accessibility of different road types is an effort to include the information of road type, number of lanes into the research model.

The output of the model showed, hospitalizations are significantly correlated with most socioeconomic variables, but not transportation exposure variables. In my research, except for travel time, null hypotheses of all other traffic exposure related variables failed to reject. Some built environmental variables such as road density, average road speed in the area, etc. cannot be altered by the residents and such variables were found to have expected direction of relation. On the other hand, the variables that are dependent on personal choice or behavior, such as travel time to work, have different finding than it was assumed. A detail research by surveying individuals with asthma and their travel pattern can help to better understand the inherent reason of such inverse relationship.

Chapter 7 Adult asthma hospitalization rate and dwelling condition

7.1 Introduction

Asthma condition is not only influenced by outdoor built environmental variables, it is also dependent on the environment where people living in. This chapter discusses about how different parameters of dwelling environment can influence adult asthma hospital visits.

7.2 Determinants of dwelling condition

For the parameters of dwelling condition, lack of plumbing and kitchen facilities, house heating fuel and housing age were considered in the research.

7.2.1 Lack of kitchen and plumbing system:

Substandard housing quality was considered as for dwelling condition. Indoor environment quality of housing units was considered with respect to kitchen and plumbing facilities. The Housing and Urban Development (HUD) considers a housing unit to be substandard/low quality if the unit lacks either complete plumbing or complete kitchen facilities (U.S. Census Bureau 2015). American Community Survey (ACS) and HUD define incomplete kitchen and plumbing in terms of absence of stove/burner, refrigerator, sink with piped water, running hot and cold water, bathtub/ shower and flush toilet.

Data on incomplete kitchen facilities and plumbing are available from ACS in the form of shapefile and have metadata explaining about different variables. The percent of housing units in any census block group that lack complete plumbing facilities and lack complete kitchen facilities was considered as a measurement of dwelling and their hygiene condition.

7.2.2 House heating fuel

In my research, I was willing to observe how the fuels used for indoor activities can influence adult asthma. For this, I wanted to investigate how cooking fuels can have impact on adult asthma. But since, the data on cooking fuel is not available at census block level, therefore I considered house heating fuel as a proxy to determine whether use of different fuels in indoor environment have impact on asthma exacerbation. Though Texas is a warm state and experience mild winter, but it does not mean the weather is never cold. Interior comfort condition is maintained during heating season (Kootin-Sanwu, V., Haberl, J. S., & Kim and Haberl 2000). Despite warmer weather than most other states, almost all Texas homes are heated and 22% of home energy is accounted for space heating (de la Vega Rodríguez, A., Casaco, A., Garcia, M., Noa, M., Carvajal, D., Arruzazabala, L., & Gonzalez 1990). Therefore, I considered house heating fuel in my study to investigate the indoor environmental condition and impact on adult asthma.

The data for house heating fuel is available from American Community Survey (ACS) 5-year estimates 2010-14. Nine different types of fuels are mentioned for house heating for occupied housing units. These are: utility gas, LP gas, fuel oil or kerosene, coal, wood, solar energy, other or no fuel used in occupied housing units. As shown in the **F**igure 7-1**,** most of the occupied housing units in the census block groups where hospitalized adult asthma patients were living used electricity (63%), followed by utility gas (34%) and bottled or LP gas (2%). Now days, very insignificant percentage of occupied housings use wood, coal or kerosene for house heating or any kind of indoor activities.

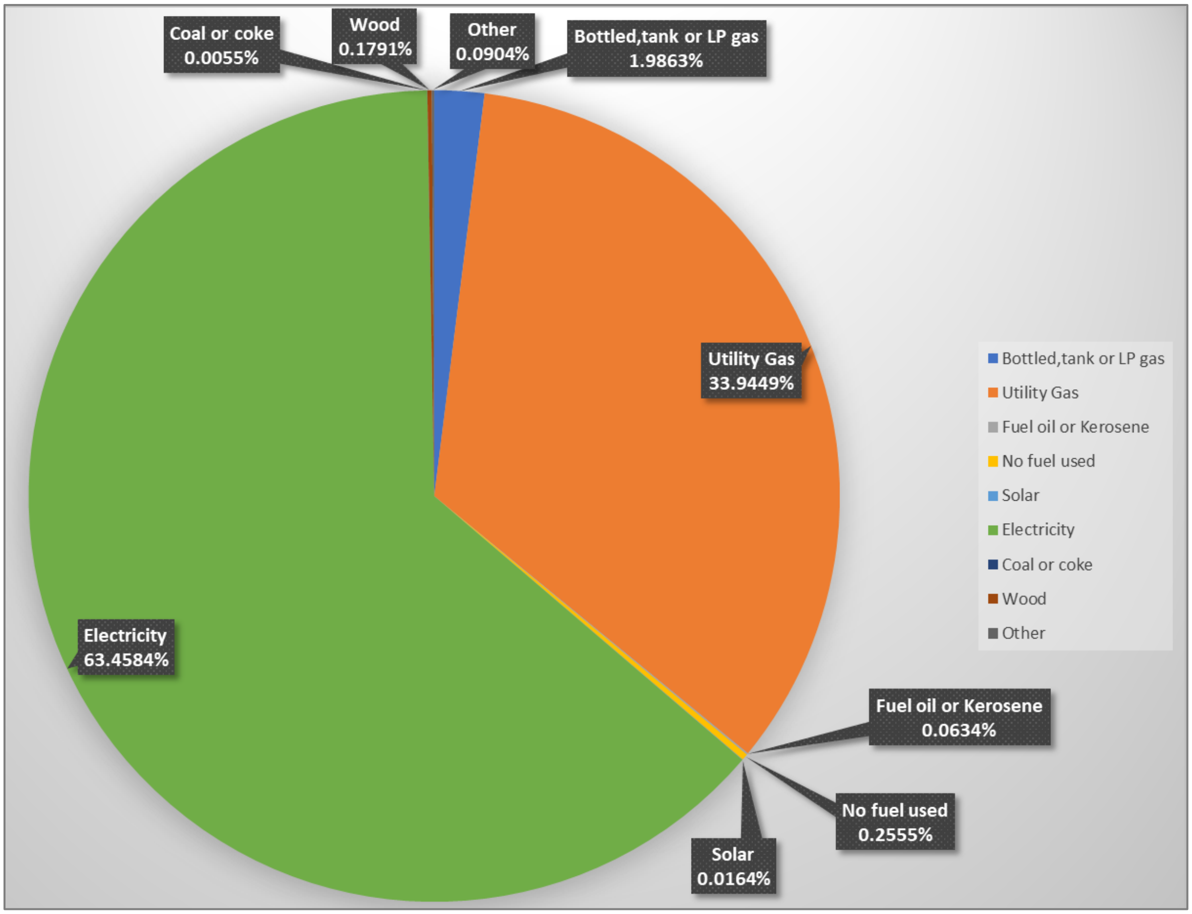

Figure 7-1 House heating fuel used by households in different CBGs

7.2.3 Housing age: built 1979 or before

Housing age was considered as a parameter to indicate indoor housing characteristics. Residential structures that were built at least 40 years ago were assumed to indicate dilapidation. Previous studies have also considered age of residential building with the assumption that older buildings are more likely to contain triggers of asthma, such as cockroaches, rodent, mold and dust mites (Corburn, Osleeb, and Porter 2006). For my research, since the data of vermin, mold and dust mites are not available at census block group level, therefore, I also considered housing age as a proxy to determine such indoor quality in different neighborhoods.

The data on housing age was obtained from ACS- 5 year estimates 2010-14. Number of housing units built in year 1970 to 1979, in 1960 to 1969, in 1950 to 1959, in1940 to 1949 and in 1939 or earlier were aggregated to get the information about housings that were built more than 40 years ago.

7.3 Dwelling condition and adult asthma exacerbation

To investigate the influence of different parameters of dwelling condition and adult asthma exacerbation, a linear regression model was developed that includes all the dwelling parameters.

Before developing the linear regression model, careful considerations of regression assumptions (such as, linearity, multicollinearity, normality etc.) were made to ensure the best result and relevant measures were took to fix them. As linearity and normality of the dependent variable was already checked in previous section, therefore, for this section, only multicollinearity among independent variables was investigated. The dwelling condition parameters considered in the model were lack of plumbing, lack of kitchen, house heating fuel and housing age. The house heating fuel consists of different fuel types. Before running the regression model, a Pearson Bivariate Correlation model was developed to identify collinearity among all the fuel types and all other dwelling parameters. The output table of correlation model is in appendix.

From the output of the Pearson Correlation model (Table in Appendix), it was evident that, percentage of units using electricity as house heating fuel was highly correlated with utility gas (correlation coefficient value 0.92). Therefore, variable for utility gas was excluded from farther consideration in the regression model to avoid multicollinearity. The linear regression model was developed with other eight home heating fuel types, lack of plumbing and kitchen facilities and housing age. Besides the dwelling variables, some socio-economic variables (race, education, income) that are strongly correlated with adult asthma hospitalization were considered in the model. It helped to improve the adjusted R2 from 0.24 to 0.333, that means 33% variance of the data can be explained by the model. The output of the regression is in Table 7.1.

Table 7-1 Influence of different parameters of dwelling condition on adult asthma hospital visits

Variables	Unstandardized Coefficients, B	Std. Error	Standardized Coefficients, Beta	t	significance
Median Household Income	-6.739E-06	.000	-.269	-13.202	.000
Population aged 25 and over without a high school diploma	.0012	.001	.038	2.417	.016
RACE: White	-.0003	.000	-.278	-16.569	.000
RACE: Black or African American	.0003	.000	.157	10.105	.000
RACE: Asian	-.0005	.000	-.129	-8.264	.000
RACE: Some other race	-.0003	.000	-.084	-5.493	.000
Bottled, tank, or LP gas* (%)	-.0037	.003	-.020	-1.280	.201
Electricity* (%)	.0005	.001	.015	.835	.404
kerosene* (%)	-.0386	.017	-.032	-2.268	.023
Coal or coke* (%)	-.0174	.116	-.002	-.150	.881
Wood* (%)	-.0156	.015	-.015	-1.025	.305
Solar energy* (%)	-.0032	.044	-.001	-.072	.943
Other Fuel* (%)	.0193	.020	.014	.946	.344
No fuel used* (%)	-.0117	.014	-.012	-.852	.394
Lacking Complete plumbing facilities: Housing units (%)	.0146	.004	.058	3.417	.001
Lacking complete kitchen facilities: Housing units (%)	.0071	.003	.038	2.240	.025
Housing units built 1979 or earlier (%)	.0010	.000	.042	2.033	.042

Note: *House heating fuel used in occupied housing units (percentage of housing units with respect to total housing units in CBGs)

Dependent variable: Adult Asthma Hospitalization Rate (log)

Adjusted R2: 0.333

The final model contains statistically significant variables (p<0.10). Among all the dwelling condition variables, percentage of housing units using kerosene for house heating, lack of plumbing facilities, lack of complete kitchen facilities and housing units built before 1979 have strong association with adult asthma hospitalization. The adjusted R2 for the final model is 0.334 which is same as the first model.

Table 7-2 Influence of statistically significant variables on adult asthma hospitalization

Variables	Unstandardized Coefficients, B	Std. Error	Standardized Coefficients, Beta	t	significance
Median Household Income	-6.9E-06	4.44E-07	-0.27486	-15.4957	0.000
Population aged 25 and over without a high school diploma	0.0012	0.000516	0.036554	2.356847	0.018
RACE: White	-0.0003	1.77E-05	-0.28107	-16.8824	0.000
RACE: Black or African American	0.0003	2.93E-05	0.161824	10.5616	0.000
RACE: Asian	-0.0005	6.51E-05	-0.12618	-8.166	0.000
RACE: Some other race	-0.0003	6.26E-05	-0.08162	-5.34781	0.000
Kerosene* (%)	-0.0395	0.016949	-0.03318	-2.3305	0.020
Lacking Complete plumbing facilities: Housing units (%)	0.0141	0.004252	0.056229	3.305051	0.001
Lacking complete kitchen facilities: Housing units (%)	0.0067	0.003181	0.035827	2.097329	0.036
Housing units built 1979 or earlier (%)	0.0009	0.000422	0.038712	2.149546	0.032

Note: *House heating fuel used in occupied housing units (percentage of housing units with respect to total housing units in CBGs)
Dependent variable: Adult Asthma Hospitalization Rate (log)
Adjusted R2: 0.334

As per the model output, except kerosene, other fuels for house heating system do not significantly influence adult asthma. The result indicates that, the census block groups where kerosene is used for home heating in most of the housing units, a smaller number of adults with severe asthma live in those areas. The impact of kerosene, coal, wood on asthma exacerbation is already widely known, so people who have asthma will avoid using those fuels in their house. Therefore, such use of kerosene or other fuel oil exists in those houses where no asthma patients live. It is to be noted from the Figure 7-1 a very small proportion of housing units (0.06%) are using kerosene as house heating fuel. Most of the housing units are using electricity (63%) and utility gas (34%) whether they have asthma patients in their houses or not.

Percentage of housing units with incomplete plumbing and incomplete kitchen systems are strongly and positively related to adult asthma hospitalization rate. Increased percentage of housing units with incomplete plumbing and kitchen system is related to increased asthma exacerbation. Lack of complete plumbing and lack of complete kitchen can cause intrusion of disease vectors (e.g. insects, rats) (Krieger and Higgins 2002). There is abundant empirical evidence that connect substandard housing condition to health problems. Poor water supply system, lack of proper toilet system, poor ventilation system in kitchen were found to relate to chronic illnesses and respiratory problem is one of them (Mckee-huger and Loosemore 2011). The findings for these two parameters of substandard housing comply with previous literature.

In addition to these parameters, age of housing units was considered as an indicator of dilapidated or substandard housing. The model output indicates increased percentage of 40 years or older buildings in area is related to higher rate of adult asthma hospitalization. There is tendency that, people with asthma severity are living in older or dilapidated residential buildings. Those dilapidated buildings have negative impact on health, specially exacerbating asthma condition.

People may consider selecting the most available house heating fuel system, but they may have limitation to make any change to the kitchen or plumbing facility by themselves. Moreover, they may choose to reside in older housing units may be because of their lower rent.

7.4 Summary

Lack of proper kitchen and plumbing system can cause intrusion of disease vectors. In addition to that since old housings were considered as a proxy for presence of vermin and mold in housing units, therefore it is obvious that, all these parameters of substandard housing are strongly and positively influencing adult asthma hospitalization in north central Texas.

On the other hand, except fuel oils or kerosene, there is no significant relationship between different house heating fuel and adult asthma hospitalization. Though kerosene or other fuel oils are used by very small percentage of housing units (0.06%) but the variable indicates a strong predictive measure. The association with the use of kerosene or fuel oils for house heating and adult asthma hospitalization is reverse. But it does not mean, use of fuel oil or kerosene can help reducing asthma. It has been long approved that such fuel oil or kerosene can exacerbate respiratory situation (Lam, N. L., Smith, K. R., Gauthier, A., & Bates 2012; de la Vega Rodríguez, A., A. Casaco, M. Garcia, M. Noa, D. Carvajal, L. Arruzazabala 1990). It means the housings who have asthma patients already avoiding those fuels in indoor activity. Therefore, it gained negative relation with the dependent variable. The findings indicate that, this region has overcome negative impact of fuel oil, kerosene, wood or coal for indoor use.

Chapter 8 Composite influence of air pollutants and other significant spatial variables on adult asthma hospitalization

8.1 Introduction

This chapter is an attempt to investigate the influence of both indoor and outdoor parameters together on adult asthma exacerbation in North central Texas region. In this chapter, I included the evaluation of factors of all categories from different geographic level on adult asthma hospitalization. The concentration of air pollutants (ozone and PM2.5) were at county level. Other variables, like socioeconomic, dwelling condition, transportation and land use parameters were at census block group level. To observe the relationship of different variables of different geographic level on adult asthma hospitalization, the Hierarchical Regression Model or Multi level model (MLM) was used. In this chapter, I tried to identify the composite influence of County and Census block group level parameters on adult asthma hospitalization rate.

8.2 Concentration of Ozone (O_3) in Counties of NCT

The Environmental Protection Agency (EPA) sets and updates the air quality standards for ground-level ozone to improve public health and environmental protection. For 12 counties of Dallas Fort Worth (DFW) region, this data is available for the year 2014 from Texas Commission on Environmental Quality (TCEQ). The ozone concentration is recorded through the continuous air monitoring stations (CAMS) and these CAMS numbers were used to get the measurements from individual sites located in DFW regions. The readings can represent concentration of ozone at county level (Khunsri, 2015). The EPA sets the standard of the primary 8-hour ozone standard and the range for “Unhealthy for Sensitive Groups” begin at 71 parts per billion (ppb). I used the “maximum value” of Eight Hours

Ozone high value days which was close to or met or exceeded 71 ppb in 2014. The data is available at this link: https://www.tceq.texas.gov/cgi-bin/compliance/monops/8hr_exceed.pl of TCEQ website.

There are ozone monitoring stations in 12 counties of north central Texas as shown in the Figure 8-1. There are no ozone monitoring stations in Erath, Palo Pinto, Somervell, and Wise county.

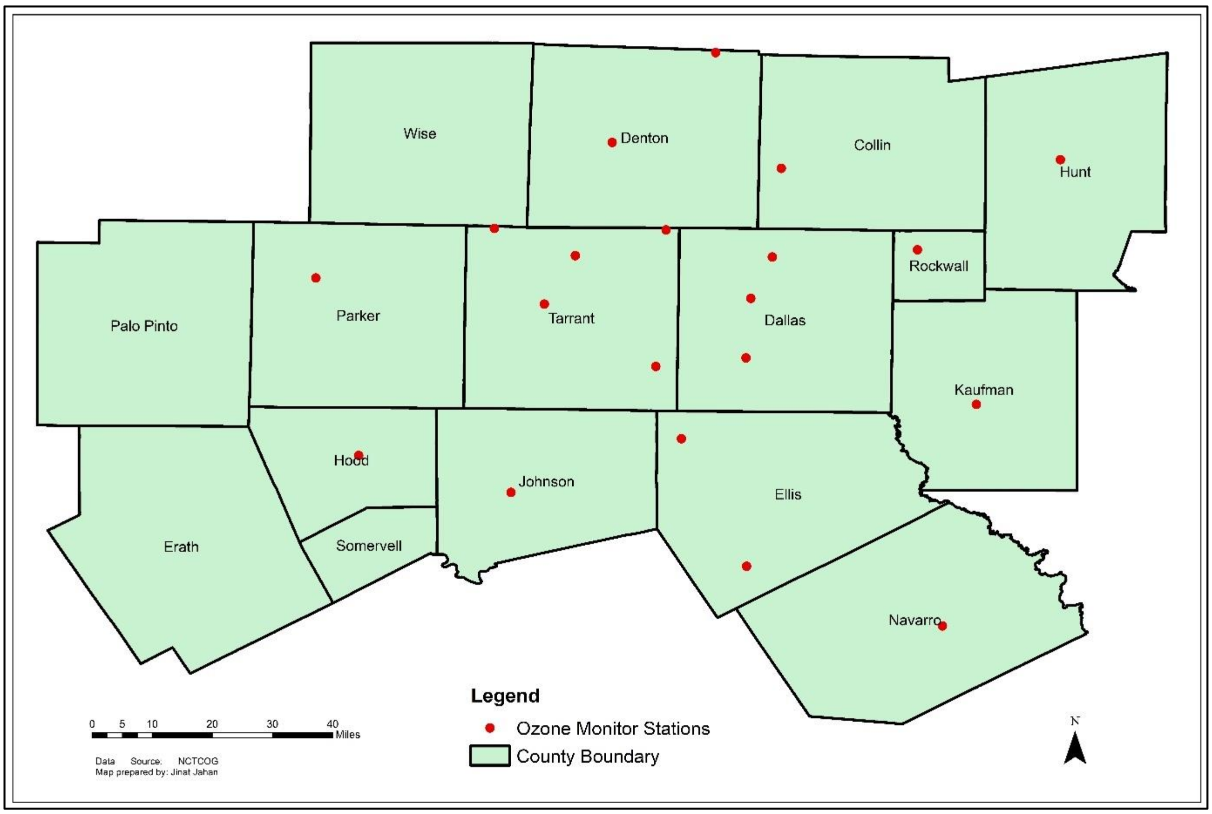

Figure 8-1 Ozone Monitoring stations in different counties of the North Central Texas

As it is to be observed from the Figure 8-1 that, some counties such as Tarrant, Dallas, Denton and Ellis counties have multiple numbers of stations. In such cases I considered data of the CAMS that recorded the highest concentration of ozone in pertinent counties. Data for the available 12 counties were considered for the same date or any nearby available dates. In this research, I considered Ozone levels for the date from 23 to 25 July 2014. During these dates, the ozone level observed to be the highest. Except Erath, Palo Pinto, Somervell and Wise county, ozone level data was available from ozone monitoring stations of following pertinent counties:

Table 8-1 Concentration of ozone in different counties of NCT in year 2014

Sl.	Ozone Monitoring Site	CAMS	County	Date	Ozone Value (ppm)
1	Frisco	31	Collin	July 25 2014	83
2	Dallas North	63	Dallas	July 25 2014	72
3	Denton Airport South	56	Denton	July 25 2014	77
4	Midlothian	52	Ellis	July 24 2014	70
5	Granbury	73	Hood	July 24 2014	87
6	Greenville	1006	Hunt	July 24 2015	70
7	Cleburne Airport	77	Johnson	July 24 2014	72
8	Kaufman	71	Kaufman	July 25 2014	68
9	Parker County	76	Parker	July 22 2014	71
10	Corsicana Airport	1051	Navarro	July 25, 2014	63
11	Rockwall Heath	69	Rockwall	May 16 2014 (only available date)	72
12	Ft. Worth Northwest	13	Tarrant	July 24 2014	81

All the counties but Ellis, Hunt, Navarro and Kaufman experienced ozone level that exceeded 71 ppb in the year 2014. In my model for concentration of ozone and its influence on adult asthma hospitalization, I considered the census block groups of these 12 counties only.

8.3 Concentration of Particulate Matter 2.5 (PM2.5)

The EPA sets the air-quality standards for Particulate Matter (PM). $PM_{2.5}$ is fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller (The United States

Environmental Protection Agency 2018). The effects of fine particles (PM2.5) on asthma have been widely confirmed by epidemiological studies (Jung et al. 2017; Williams 2019; Pope et al. 2016). The EPA sets the 24-hour PM2.5 standard to 35 μg/m^3 and the level of the annual PM2.5 standard at 12 μg/m^3 (The U.S. Environmental Protection Agency, n.d.-c). I will consider the average daily density of fine particulate matter ($PM_{2.5}$) in micrograms per cubic meter for the year 2014 available for all counties of DFW area available from 'Key Finding Reports: County Health Rankings and Road Maps' (link: https://www.countyhealthrankings.org/app/texas/2014/measure/factors/125/map).

The average concentration of PM 2.5 in the year 2014 in all the counties of the study area was as follow:

Table 8-2 Concentration of PM 2.5 (μg/m3) in different counties of the NCT region

	County	Concentration of PM 2.5 (μg/m3)
1	Collin	10
2	Dallas	9.9
3	Denton	9.9
4	Ellis	9.6
5	Erath	9.6
6	Hood	9.6
7	Hunt	10
8	Johnson	9.6
9	Kaufman	9.8
10	Navarro	9.4
11	Palo Pinto	9.7
12	Parker	9.8
13	Rockwall	10
14	Somervell	9.5
15	Tarrant	9.8
16	Wise	9.9

The variation of PM2.5 in different counties can be visible from Figure 8-2.

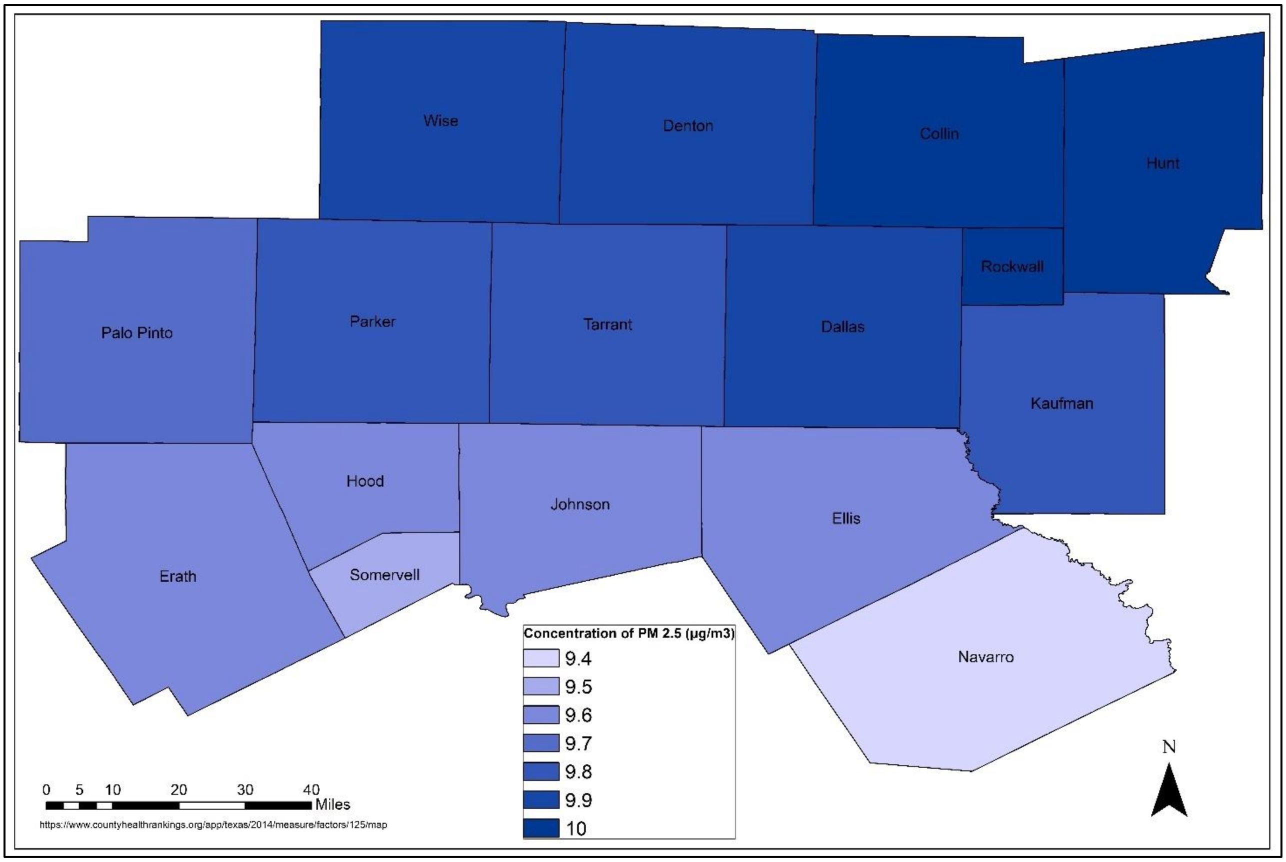

Figure 8-2 Concentration of PM 2.5 (µg/m3) in different counties of the NCT region

8.4 Evaluating the Cumulative impact of county and census block group variables by applying multilevel modeling

8.4.1 Why Multilevel modeling

Parameters of this research are in different geographic levels or in other words nested in different levels (individuals are nested in census block groups and census block groups are nested in counties). Previous studies suggested that, when research data are nested, statistical approaches to the data must account for the multilevel nature of the data or it may risk errors in interpretation (Dickinson, Miriam and Basu 2005). Bryk, Stephen W. Raudenbush (2002) mentioned that, multilevel models (also known as hierarchical linear models or nested data models) are statistical methods of parameters that vary at more than one level. Due to several benefits of the model, literature supported the application of multilevel modeling for researches that contain data from different geographic stages.

First, multilevel modeling allows researchers to test hypotheses that cannot be tested with conventional ANOVA and regression approaches (Silvia 2007). For example, Dickinson and Basu (2005) applied multilevel (hierarchical) models to study patients that are nested within different health care systems and contrasted the results with traditional linear regression models. Their multilevel models demonstrated that the effects of physician-level activities vary from clinic to clinic as well as between rural and urban settings; this variability was undetected in traditional linear regression approaches.

Second, the multilevel modeling can harness a vast range of dataset that researchers are collecting. Sometimes researchers average the information of upper level (for example average the information of city, county or MSA) and consider that score for the lower level (individual, community or neighborhood). After all the work to collect extensive data on different geographic level, averaging can exploit the statistical strength of assessment. In such cases, multilevel modeling can be applied to explore relation of variables of different level that are obscured by averaging (Silvia, 2007).

Finally, many researchers considered to use multilevel modeling for health related studies as human/patient data are obtained at individual level and they are nested within hierarchical or clustered structures (Center for Mulitlevel Modeling, n.d.). Moreover, “space” matters for health and space/geography can produce variation in health resulting in geographic clusters of poor or good health (Arcaya, M, Brewster, M. Zigler 2012). For all these reasons, this research explored the geographical distribution and severity of adult asthma patients with respect to the influential surrounding outdoor as well as indoor determinants in the north central Texas by applying multilevel modeling. The structure of the model is shown in Figure 8-3.

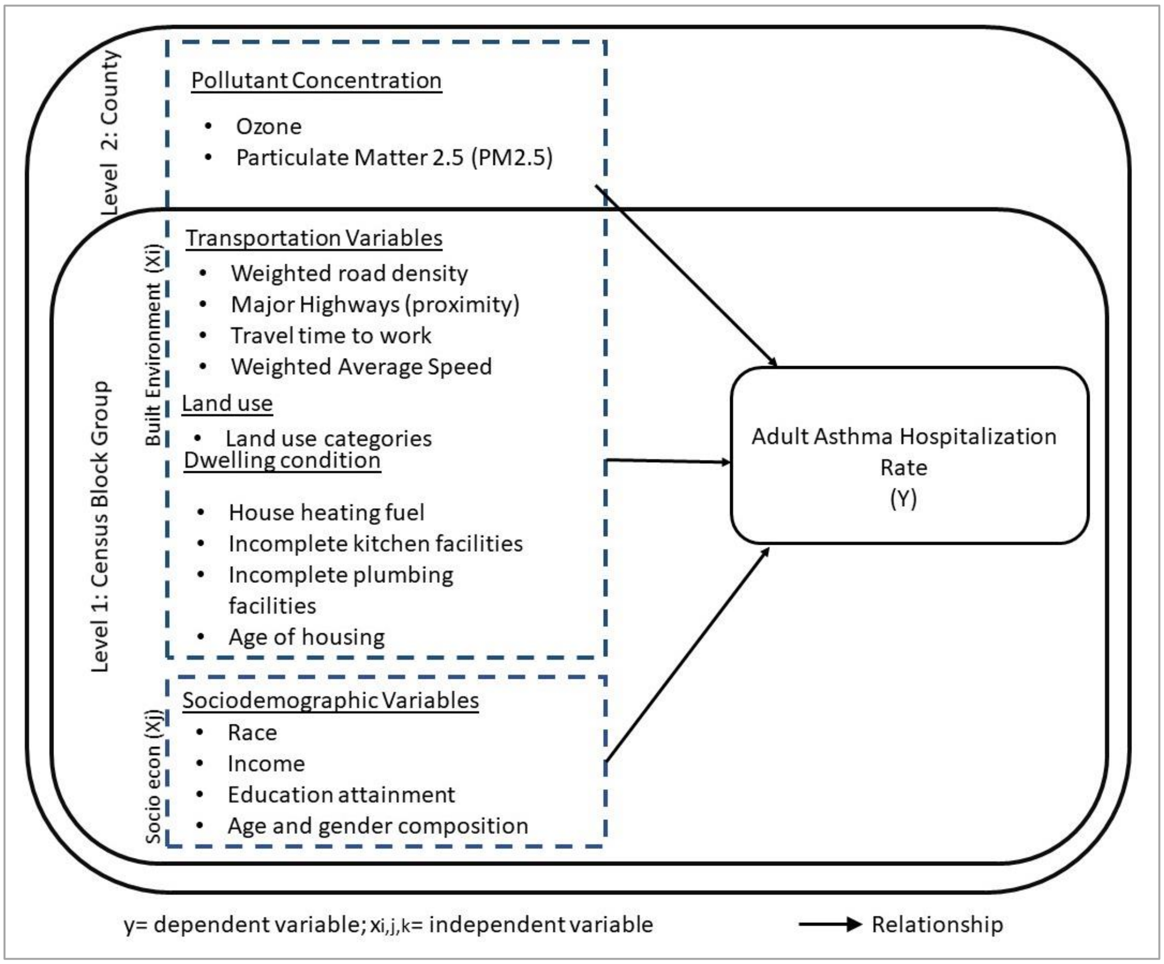

Figure 8-3 Structure of the Multilevel/ Hierarchical Model of the study

8.4.2 the HLM/MLM model output

In this study, level 1 or lower level data is the adult asthma hospitalization rate at census block groups. On the other hand, concentration of ozone and particulate matter 2.5 are at county level, which is upper level data or level 2 data. The unit of analysis (i.e. census block group) is nested within the higher level (county) data. Multilevel modeling can be used to see the relationship among the data of various levels, like, household within neighborhood, neighborhood within metropolitan, metropolitan within state, etc. In this study, 2-level model has been developed with census block group level and country level data. To observe the relationship between adult asthma hospitalization rate and concentration of pollution (ozone, PM 2.5) at county level, the "Linear Mixed Model" tool of SPSS has been used.

Since ozone concentration data is available for 12 counties where ozone monitoring stations are located and PM2.5 concentration data is available for all 16 counties of this region, therefore three different multilevel models were developed. In these three models, the level 1 (CBG level) variables contained all the significant independent variables found in land use, transportation and dwelling condition chapters and at level 2 (county level) the first model contained information of ozone for 12 counties, the second model contained information of ozone and PM2.5 for 12 counties and the third model was developed for 16 counties with available PM2.5 data for all the counties.

8.4.3 HLM/MLM Model 1: Ozone data at County level (12 Counties)

This model was developed for 12 counties (Collin, Dallas, Denton, Ellis, Hood, Hunt, Johnson, Kaufman, Parker, Navarro, Rockwall and Tarrant), since Ozone level data was available for these 12 counties. The adult asthma hospitalization rate and other independent variables at CBG level were considered for these 12 counties as well. The dependent variable of the model 1 is adult asthma hospitalization rate in CBGs (log). The independent variables of level 1 (census block group level) were statistically significant variables from land use, socioeconomic, dwelling condition and transportation parameters discussed in pertinent chapters. In this model, I considered Median Household Income, education, race, total travel time to work, percentage of cemeteries, group quarters, mobile home, parking lot, railroad, timberland, vacant plot, percentage of housing units that use kerosene for house heating, percentage of housing units with incomplete kitchen and plumbing facility and percentage of housing units that are 40 years or older in the level 1. These are all the significant independent variables at level 1 (CBG level) found in previous chapters.

In level 2 (county level), concentration of ozone was considered.

The output table for the model, which provides the coefficient and significance level (p value) for the variables is as follow:

Table 8-3 -Model 1: Multilevel model (MLM) analysis for impact of county level (ozone concentration) and Census Block Group level significant variables on adult asthma hospitalization rate (model for 12 counties of North Central Texas)

Variable		Estimate	Std. Error	df	t	Sig.
Intercept		-.746743	1.029166	8.915	-.726	.487
Level 1 (Census Block Group)	Median Household Income	-6.589847E-006	4.547784E-007	3214.859	-14.490	.000
	Population aged 25 and over without a high school diploma	.001071	.000504	3207.298	2.124	.034
	RACE: White	-.000207	3.520380E-005	3224.465	-5.867	.000
	RACE: Black or African American	.000404	3.884898E-005	3211.523	10.395	.000
	RACE: Asian	-.000326	7.439676E-005	3211.735	-4.380	.000
	RACE: Some other race	-.000198	6.817629E-005	3210.952	-2.903	.004
	Total Travel Time to Work: Workers 16 years and over who did not work at home	-.000240	6.652415E-005	3217.627	-3.607	.000
	Cemeteries (%)	-.010194	.004386	3213.532	-2.324	.020
	Group quarters (%)	-.037078	.009429	3206.796	-3.932	.000
	Mobile home (%)	.012308	.003443	3217.640	3.575	.000
	Parking (%)	-.011326	.007871	3205.539	-1.439	.150
	Railroad (%)	.007633	.005530	3207.499	1.380	.168
	Timberland (%)	-.009489	.005267	2482.802	-1.802	.072
	Vacant (%)	.006281	.001148	3224.020	5.471	.000
	Kerosene* (%)	-.044164	.016620	3219.910	-2.657	.008
	Lacking Complete plumbing facilities: Housing units (%)	.009909	.004204	3210.730	2.357	.018
	Lacking complete kitchen facilities: Housing units (%)	.006332	.003162	3215.289	2.003	.045
	Housing units built 1979 or earlier (%)	.001467	.000468	3220.464	3.135	.002
Level 2 (County)	Ozone concentration	-.002284	.013876	8.842	-.165	.873

Note: *House heating fuel used in occupied housing units (percentage of housing units with respect to total housing units in CBGs)

Dependent variable: Adult asthma hospitalization rate (log)

The equation of model output is as follow:

Level-1 (Geographic level- Census block group)

Y = B0 - B1*(Median Household Income) + B2*(Population aged 25 and over without a high school diploma) - B3*(RACE: White) + B4*(RACE: Black) - B5*(RACE: Asian) - B6*(RACE: Some other race) - B7*(Total Travel Time to Work) - B8*(Cemeteries (%)) - B9*(Group quarters (%))+ B10*(Mobile home (%)) - B11*(Parking (%))+ B12*(Railroad (%)) - B13*(Timberland (%)) + B14*(Vacant (%)) - B15*(Kerosene* (%)) + B16*(Lacking Complete plumbing facilities: Housing units (%)) + B17*(Lacking complete kitchen facilities: Housing units (%)) + B18*(Housing units built 1979 or earlier (%)) + R

Level-2 (Geographic level- County)

B0 = G00 - G01*(OZONE level) + U0

B1 = G10

B2 = G20

B3 = G30

B4 = G40

Mixed model:

Y = G00 - G01*(OZONE level) + U0- B1*(Median Household Income) + B2*(Population aged 25 and over without a high school diploma) - B3*(RACE: White) + B4*(RACE: Black) - B5*(RACE: Asian) - B6*(RACE: Some other race) - B7*(Total Travel Time to Work) - B8*(Cemeteries (%)) - B9*(Group quarters (%))+ B10*(Mobile home (%)) - B11*(Parking (%)) + B12*(Railroad (%)) - B13*(Timberland (%)) + B14*(Vacant (%)) - B15*(Kerosene* (%)) + B16*(Lacking Complete plumbing facilities: Housing units (%)) + B17*(Lacking complete kitchen facilities: Housing units (%)) + B18*(Housing units built 1979 or earlier (%)) + R

This is a Random Intercept Model. The intercept (B0) for the function changes with respect to the variables in level 2, but the coefficients (B1, B2, B3, …, B18) of the variables in level 1 remain same in this case. This indicates that, with different ozone concentration in different counties can lead to different adult asthma hospitalization in CBGs despite of having same travel time to work, or same proportion of timberland, cemeteries, group quarter, mobile home, parking, railroad, vacant land or same proportion of housing units with incomplete kitchen and plumbing facilities or same median household income, education, racial composition in census block groups.

From the MLM output table (Table 8-4), it is evident that, ozone concentration is statistically insignificant to have influence on adult asthma exacerbation. Ozone was found negatively related to asthma hospitalization rate. Previous studies also found there were almost no statistically significant correlations for most of relationship between ozone exposure and asthma hospitalization rates in north Texas region (Gorai et al. 2015; Khunsri 2015). There is ozone alert system for bad ozone days ranging from high alert levels (maroon color- indicate hazardous) to lower alert level (green color-indicate good). An ozone alert is issued every time the ozone level increases (orange level, more than 71 ppb) that is harmful for sensitive group of people like children, elderly with respiratory health issues and workers who work outside for a long time. During an Ozone Alert Day, the sensitive groups are advised to reduce prolonged outside activities and people with asthma are advised to follow their asthma action plan and keep their relief medicine handy (City of Dallas 2018). A research by Carls (2010) found that in ozone day alert, people take protective measures, as her model identified Higher alert levels were associated with a protective effect of ozone alerts than lower alert levels.

In my research, I used the “maximum value” of Eight Hours Ozone high value days which was close to or met or exceeded 71 ppb (Unhealthy for Sensitive Groups) in 2014. In MLM model output, the negative coefficient for concentration of ozone can be explained as asthmatic adult people are cautious and take measures during bad ozone day therefore asthma hospitalization rates at census block groups do not increase with the increase of ozone concentration in the counties.

For level 1 (census block group) of the model, except percentage of parking lots and railroads, the relationships of all other significant transportation, land use, dwelling condition and sociodemographic variables with adult asthma hospitalization rate are consistent throughout the research. In this hierarchical linear model, the percentage of parking lots and percentage of railroads in CBGs became insignificant ($p > 0.10$) while these parameters were found significant in land use chapter. Though the direction of their association with dependent variable remained same.

8.4.4 HLM/MLM Model 2: PM2.5 and Ozone concentration at County level (12 Counties)

The second model contains concentration of PM2.5 besides concentration of Ozone in level 2 (County level). Though information of PM2.5 concentration is available for all 16 counties, but this second model was developed for 12 counties since the ozone information is available for 12 counties where ozone monitoring stations are located.

For level 1 (census block group level) everything remained same as Model 1. All significant variables from land use, transportation and dwelling condition parameters were considered in the level 1 of this model. The Table 8-4 provides output for the model:

Table 8-4 - Model 2: Multilevel model (MLM) analysis for impact of county level (PM2.5 and ozone concentration) and Census Block Group level significant variables on adult asthma hospitalization rate (model for all 12 counties of North Central Texas)

Variables		Estimate	Std. Error	df	t	Sig.
Intercept		-10.787517	4.014719	11.668	-2.687	.020
Level 1 (Census Block Group)	Median Household Income	-6.605829E-006	4.546994E-007	3216.729	-14.528	.000
	Population aged 25 and over without a high school diploma	.001066	.000504	3211.941	2.116	.034
	RACE: White	-.000206	3.517831E-005	3224.887	-5.853	.000
	RACE: Black or African American	.000404	3.883321E-005	3216.593	10.402	.000
	RACE: Asian	-.000327	7.436613E-005	3216.477	-4.391	.000
	RACE: Some other race	-.000199	6.815380E-005	3215.197	-2.925	.003
	Total Travel Time to Work: Workers 16 years and over who did not work at home	-.000241	6.650097E-005	3220.591	-3.630	.000
	Cemeteries (%)	-.010090	.004385	3216.799	-2.301	.021
	Group quarters (%)	-.037210	.009426	3211.144	-3.948	.000
	Mobile home (%)	.012444	.003441	3220.339	3.616	.000
	Parking (%)	-.011331	.007868	3210.234	-1.440	.150
	Railroad (%)	.007650	.005528	3212.268	1.384	.167
	Timberland (%)	-.008638	.005283	2717.077	-1.635	.102
	Vacant (%)	.006215	.001147	3224.991	5.417	.000
	Kerosene* (%)	-.044570	.016612	3222.649	-2.683	.007
	Lacking Complete plumbing facilities: Housing units (%)	.009968	.004203	3215.388	2.372	.018
	Lacking complete kitchen facilities: Housing units (%)	.006409	.003160	3219.612	2.028	.043
	Housing units built 1979 or earlier (%)	.001464	.000467	3224.317	3.132	.002
Level 2 (County)	Ozone concentration	-.010492	.012380	12.291	-.847	.413
	PM2.5 concentration	1.087380	.427385	11.970	2.544	.026

Note: *House heating fuel used in occupied housing units (percentage of housing units with respect to total housing units in CBGs)

Dependent variable: Adult asthma hospitalization rate (log)

The equation of model 2 output is as follow:

Level-1 (Geographic level- Census block group)

Y = B0 - B1*(Median Household Income) + B2*(Population aged 25 and over without a high school diploma) - B3*(RACE: White) + B4*(RACE: Black) - B5*(RACE: Asian) - B6*(RACE: Some other race) - B7*(Total Travel Time to Work) - B8*(Cemeteries (%)) - B9*(Group quarters (%))+ B10*(Mobile home (%)) - B11*(Parking (%))+ B12*(Railroad (%)) - B13*(Timberland (%)) + B14*(Vacant (%)) - B15*(Kerosene* (%)) + B16*(Lacking Complete plumbing facilities: Housing units (%)) + B17*(Lacking complete kitchen facilities: Housing units (%)) + B18*(Housing units built 1979 or earlier (%)) + R

Level-2 (Geographic level- County)

B0 = G00 - G01*(OZONE level) + G02*(PM2.5) + U0

B1 = G10

B2 = G20

B3 = G30

B4 = G40

Mixed model:

Y = G00 - G01*(OZONE level) + G02*(PM2.5) + U0- B1*(Median Household Income) + B2*(Population aged 25 and over without a high school diploma) - B3*(RACE: White) + B4*(RACE: Black) - B5*(RACE: Asian) - B6*(RACE: Some other race) - B7*(Total Travel Time to Work) - B8*(Cemeteries (%)) - B9*(Group quarters (%))+ B10*(Mobile home (%)) - B11*(Parking (%)) + B12*(Railroad (%)) - B13*(Timberland (%)) + B14*(Vacant (%)) - B15*(Kerosene* (%)) + B16*(Lacking Complete plumbing facilities: Housing units (%)) + B17*(Lacking complete kitchen facilities: Housing units (%)) + B18*(Housing units built 1979 or earlier (%)) + R

As this is also a Random Intercept Model, therefore it is to be noted that, inclusion of one more variable in Level 2 did not considerably change the coefficients of level 1

(Census Block Group level) variables. Rather, coefficient of level 2 for ozone concentration changed in this model than it was in model 1 after incorporating PM2.5 concentration as an independent variable in level 2. The intercept (B0) for the function changes with respect to the variables in level 2, but the coefficients (B1, B2, B3, …, B18) of the variables in level 1 remain same in this case. This indicates that, despite every other parameter remain same in census block group level, change in concentration of pollutants (ozone and PM2.5) at county level can change the adult asthma hospitalization rate at census block groups.

Similar to the HLM model 1, also in this model the concentration of ozone at counties are insignificant and negatively associated with adult asthma hospitalization at Census Block Groups. Among two independent variables in level 2, only concentration of PM2.5 is statistically significant.

The positive coefficient of "concentration of PM 2.5" indicates that, with the increased concentration of PM2.5(µg/m3) in the air, there would be increased adult asthma hospitalization rate in census block groups of that county. Previous research identified, particulate matters with smaller diameters (2.5 micro meters or less) have damaging health effects (Williams 2019; Mcentee and Ogneva-himmelberger 2008). These can be inhaled and can damage respiratory health as studies have found elevated concentration of particulate matter is associated with increase in hospital counts for all patients with asthma (James et al. 2018; Mcentee and Ogneva-himmelberger 2008; Williams 2019). The relationship between PM2.5 concentration in Counties and adult asthma hospitalization rate in CBGs complies with previous findings.

In the level 1 of the model 2, besides percentage of parking lot and railroad, the percentage of timberland in census block groups became insignificant to predict any relationship with adult asthma hospitalization. In the model 1, only parking lot and railroads became insignificant and in model 2, after inclusion of PM2.5 concentration at level 2, the percentage of timberland also became insignificant. This indicates that, other variables of this model can better explain the relationship with adult asthma hospitalization. Though the direction of coefficients is same for all the variables of level 1 as it was in Model 1 as well as throughout the research.

8.4.5 HLM/MLM Model 3: PM2.5 concentration at County level (16 Counties)

The third hierarchical linear model was developed for PM2.5 concentration at level 2 (counties). Since data of ozone concentration is not available for all the 16 counties, therefore the third model considers the concentration for PM2.5 only. Information of PM2.5 concentration was available for all the 16 counties; therefore, this model is developed for all the counties of the study area. Like the first and second MLM models, in level 1 of this model, all significant variables from land use, transportation and dwelling condition chapters were considered. The Table 8-5 provides output for the model:

Table 8-5 - Model 3: Multilevel model (MLM) analysis for impact of county level (PM2.5 concentration) and Census Block Group level significant variables on adult asthma hospitalization rate (model for all 16 counties of North Central Texas)

Parameter		Estimate	Std. Error	df	t	Sig.
Intercept		-12.381211	4.118620	13.175	-3.006	.010
Level 1 (Census Block Group)	Median Household Income	-6.632005E-006	4.526405E-007	3256.146	-14.652	.000
	Population aged 25 and over without a high school diploma	.001021	.000502	3249.885	2.033	.042
	RACE: White	-.000207	3.502430E-005	3263.998	-5.918	.000
	RACE: Black or African American	.000401	3.875080E-005	3253.198	10.360	.000
	RACE: Asian	-.000332	7.421656E-005	3254.824	-4.472	.000
	RACE: Some other race	-.000203	6.799849E-005	3252.177	-2.987	.003
	Total Travel Time to Work: Workers 16 years and over who did not work at home	-.000234	6.625983E-005	3259.021	-3.538	.000
	Cemeteries (%)	-.010004	.004379	3253.856	-2.285	.022
	Group quarters (%)	-.037041	.009412	3248.574	-3.936	.000
	Mobile home (%)	.013062	.003425	3257.368	3.814	.000
	Parking (%)	-.011401	.007857	3247.376	-1.451	.147
	Railroad (%)	.007645	.005521	3249.510	1.385	.166
	Timberland (%)	-.008912	.005233	2783.152	-1.703	.089
	Vacant (%)	.006271	.001144	3263.794	5.483	.000
	Kerosene* (%)	-.044637	.016527	3260.253	-2.701	.007
	Lacking Complete plumbing facilities: Housing units (%)	.009992	.004167	3261.311	2.398	.017
	Lacking complete kitchen facilities: Housing units (%)	.005649	.003138	3260.488	1.800	.072
	Housing units built 1979 or earlier (%)	.001495	.000465	3263.474	3.215	.001
Level 2 (County)	PM2.5 concentration	1.171670	.419968	13.079	2.790	.015

Note: *House heating fuel used in occupied housing units (percentage of housing units with respect to total housing units in CBGs)

Dependent variable: Adult asthma hospitalization rate (log)

The equation of model 3 output is as follow:

Level-1 (Geographic level- Census block group)

Y = B0 - B1*(Median Household Income) + B2*(Population aged 25 and over without a high school diploma) - B3*(RACE: White) + B4*(RACE: Black) - B5*(RACE: Asian) - B6*(RACE: Some other race) - B7*(Total Travel Time to Work) - B8*(Cemeteries (%)) - B9*(Group quarters (%))+ B10*(Mobile home (%)) - B11*(Parking (%))+ B12*(Railroad (%)) - B13*(Timberland (%)) + B14*(Vacant (%)) - B15*(Kerosene* (%)) + B16*(Lacking Complete plumbing facilities: Housing units (%)) + B17*(Lacking complete kitchen facilities: Housing units (%)) + B18*(Housing units built 1979 or earlier (%)) + R

Level-2 (Geographic level- County)

B0 = G00 + G01*(PM2.5) + U0

B1 = G10

B2 = G20

B3 = G30

B4 = G40

Mixed model:

Y = G00 + G01 *(PM2.5) + U0- B1*(Median Household Income) + B2*(Population aged 25 and over without a high school diploma) - B3*(RACE: White) + B4*(RACE: Black) - B5*(RACE: Asian) - B6*(RACE: Some other race) - B7*(Total Travel Time to Work) - B8*(Cemeteries (%)) - B9*(Group quarters (%))+ B10*(Mobile home (%)) - B11*(Parking (%)) + B12*(Railroad (%)) - B13*(Timberland (%)) + B14*(Vacant (%)) - B15*(Kerosene* (%)) + B16*(Lacking Complete plumbing facilities: Housing units (%)) + B17*(Lacking complete kitchen facilities: Housing units (%)) + B18*(Housing units built 1979 or earlier (%)) + R

In this third model, where only PM2.5 concentration for 16 counties is considered, the PM2.5 concentration found to be significantly and positively related to adult asthma hospitalization rate in CBGs. All other variables at level 1 remained same. This pollutant parameter was also significantly and positively related to adult asthma hospitalization in Model 2. Compared to the second model, the coefficient of PM2.5 concentration increased from 1.08 to 1.17 in this third model. This is Indicating an overall increase of adult asthma aggravation with the increase of PM2.5 concentration in all over the region.

This multilevel study consistently found significant and positive association between average daily density of fine particulate matter (PM2.5) and adult asthma hospitalization rate. In previous section it has already been discussed that, inhalation of such fine particles elevates the risk of asthma related hospitalization (Williams 2019). In north central Texas region, this pollutant is coming from several sources including combustion of diesel, gasoline or fossil fuel used for transportation as well as natural gas or coal used in industrial processes (Ridlington, Elizabeth, Gideon Weissman 2020). In this auto-oriented region, vehicular emission is one of the major sources of such pollutant.

In level 1 of the model, there is no considerable change in coefficients since this is a random intercept model. This indicates that, with different PM2.5 concentration in different county can lead to different adult asthma hospitalization in CBGs despite of constant land use, transportation and dwelling parameters in census block group levels.

8.5 Summary

The relationship between health and surrounding environment is a very complex phenomenon. This research is an effort to investigate and present a very small portion of this complex phenomenon for north central Texas region. Since, the environment from micro to macro scale can have impact on adult asthma severity, therefore an effort was made to investigate the influence of county as well as neighborhood level environment on the hospital admission. The condition of the adult patient must be severe enough that he or she needed to be hospitalized. The purpose of this chapter was to observe if there is any influence of ozone and PM2.5 that can aggravate the condition of severe asthma patients that required them to be hospitalized. The model output indicates, with everything remains unchanged in census block group level, there is no significance of ozone concentration to influence the condition of adult asthma patients. Therefore, the null hypotheses “there is no association between asthma hospitalization and ozone concentration” was failed to reject. On the other hand, if everything remains same in level 1 (census block groups), the PM2.5 concentration at counties have significantly positive relationship with adult asthma exacerbation. Therefore, the null hypothesis “there is no relationship between PM2.5 concentration and adult asthma hospitalization” was rejected.

Chapter 9 Recommendations

This chapter discusses about policy recommendations that can be followed by urban planners, policy makers and health practitioners for remedial of asthma exacerbation. Based on the major findings from previous chapters, I tried to list following policy recommendations from different built environmental and socio demographic aspects that can help to manage asthma situation in this region.

9.1 Recommendations regarding social determinants

The data from this study exhibits strong evidence of ongoing health related disparities for adult asthma patients living in the NCT region. The results of the study indicate female, minority group of people (African American, American Indian) were mostly admitted to the hospital due to asthma exacerbation. Patients of minority groups were mostly uninsured. Moreover, if considered at neighborhood level; areas with low income, low education level and high concentration of African American Population were associated with increased adult asthma hospitalization rate. The socioeconomic aspects of asthma severity both at patients' level and neighborhood level urge for social policies as a mean to improve the condition of socially distressed asthmatic people.

It is important to ensure access to health facilities for asthma patients regardless of age, gender, race, or income level. Asthma prevention and treatment should be more reachable to the patients irrespective of type of insurances. Rather, the treatment should be less private and more integrated into public health services. In addition, quality of care is also important to ensure. Therefore, interventions targeting health systems that address discrimination and ensure access to care should be initiated in asthma mitigation plan. Though the 'Texas Asthma Plan' developed by the Asthma Coalition of Texas (ACT), in partnership with the Texas Asthma Program at the Department of State Health Services (DSHS) is aimed to identify environmental justice issues for asthma disparities that disproportionately impact minority groups. But the results of my study indicate that success of such aims are still not on the ground and may require proper execution of the plan.

An intervention from federal level may help to bring integrated change into the health care system. With the initiative of federal government, the public and private health industries can effectively change health care system for asthma treatment to reduce obstacles for the minority as well as low income group of people and increase access to proper care when needed. Besides initiative from the federal level, efforts at state and then at more local level can ensure management of asthma severity for distressed group of people. Policy makers and health providers at local level can be trained to understand about the obstacles and needs of distressed groups as well as how to effectively work with the changed healthcare system.

In addition to this, to work efficiently with the existing asthma patients of distressed community it is important to set priority and scale. Areas with the least median income, high proportion of people with low education and high concentration of minority population can be prioritized as the most distressed community to facilitate with asthma management activities. Based on the severity of asthma, the scale may vary from micro to macro scale, here micro scale can be considered at individual or household level and macro scale can be considered at county level. Based on the capacity of local government and health care provisions, asthma education and public awareness programs can be introduced to these different scales. Local government and health care providers can also make a collaboration with ethnic centric community and racial organizations to operate community outreach and asthma education program.

Furthermore, environmental justice policies should be incorporated in the work principles of urban planning agencies which can help the socially distressed asthma population. In collaboration with the public health agencies, urban planners can help identify the spatial pattern of asthma severity and help to suggest for less segregated areas.

9.2 Recommendations regarding land use

My study found vacant land, mobile home and railroads were strongly associated to increased asthma exacerbation in neighborhoods. On the other hand, woods or timberlands/natural green spaces, group quarters and cemeteries were found strongly associated to decrease asthma severity in neighborhoods. Though industrial and commercial land uses are important land use as mentioned by different literature but result of my model indicated insignificant relationship with adult asthma hospitalization rate.

Existing vacant and underdeveloped lands in neighborhoods can be converted into urban green spaces through “vacant land greening” initiative. For this, exemplary work of Cleveland and Philadelphia can be followed. In Cleveland, vacant lands were renovated as community gardens, greener parks, and farms. The second pioneering city Philadelphia also converted the vacant lots into community gardens and recently they have broadened the scope to conduct a comprehensive and multifaceted citywide greening activity (Mallach 2018). Research showed such “vacant lot greening” initiative resulted city of Philadelphia to be healthier and safer (Branas et al. 2011). Urban planners of different cities of north central Texas regions can assess which areas have the most potential vacant lands that are influencing asthma situation and can be converted into green spaces with the available budget. Such initiative can be incorporated into the local land use zoning plan and in land use maintenance programs. Urban planners and policy makers can set basic rules for such greening initiatives. Residents and neighborhood community groups in partnership with local government and development corporations can maintain vacant lands of their area by removing trash, weeding or mowing green spaces.

Since existence of natural green space or timberlands were found to reduce asthma hospitalization rate in NCT region, therefore, vacant lot greening initiative with trees and grass would help to provide fresh air for asthma patients living in those areas. Moreover, if any cremation place exists in any neighborhood, those should be maintained as green spaces and trees should be planted in such areas. These green spaces would not only help improving the condition of asthma patients but would also help other residents to maintain a better quality of life.

Externalities of other land uses on asthma situation should also be carefully considered. As presence of railroads in neighborhood found to be strongly and positively associated with asthma hospitalization rate, therefore, planners, health care providers and policy makers should control the impact of such land from pertinent perspectives. Urban planners can plan for residential area and railroads to be in safer distance. The areas with railroads should have natural vegetation barriers between railroads and residential areas. This can help to sequester railroad related air pollution. Health care providers and local government policy makers can raise awareness among patients with respiratory diseases to live in areas distant from rail facilities.

Though results of my study showed no significant relationship of adult asthma hospitalization with commercial and industrial uses but still it is important to insulate the living places of asthma patients from such land uses. This is because, previous studies found such land uses to have negative influence on asthma and other respiratory problems (Ebisu et al. 2011; Chen, Z., Salam, M. T., Eckel, S. P., Breton, C. V., & Gilliland 2015). Through land use zoning system, such land uses can be separated from residential land uses. Health care guidelines for residents to select living place in certain areas should be provided by the housing authorities. This can help and encourage the vulnerable group of people to live in areas isolated from commercial, industrial and railroad facilities

9.3 Recommendations regarding transportation variables

Based on different literature, I considered four different traffic related variables as a proxy to measure exposure to traffic air pollution and their impact on asthma patients. Among four transportation variables in the model, only one variable “total travel time to work” was statistically significant. Though other variables “weighted road density in CBGs”, “weighted average speed of traffic in CBGs” and “proximity to major highways” were not statistically significant but the results do show expected signs. Surprisingly, sign for travel time to work from CBGs was negative, indicating CBGs with longer commuting time had reduced hospitalization rate for adult asthma. As it was assumed that higher commuting time indicates exposure to traffic environment for longer period hence can exacerbate asthma situation. But in this auto-oriented region, adults with asthma might choose to live closure to their workplace as a precaution of their health condition. Such travel behavior in terms of commuting time should be encouraged and should be continued in future. Besides such travel for work, any wasteful auto travel should be discouraged.

Asthma patients can control their travel behavior but cannot manage the built environmental features of their neighborhood. Asthmatic people or any resident might not be aware about the amount of road or speed of traffic in their residential area. The result of a positive relationship between road density, traffic speed and proximity to major roads and adult asthma hospital visit rate suggest that to reduce asthma exacerbation, it is important to have intervention from transportation planning as well as from housing authority perspective. An inventory or index for traffic infrastructure should be developed by transportation planners of pertinent local authorities mentioning about the existing amount of road, traffic speed and distance from the nearest major highways. Such index can be shared with housing authorities or health providers who can inform the asthmatic residents and help them locate in an area that have reduced road density, traffic speed and distant form major roads. Besides, such index can be shared with public in local authority's website which can help asthmatic patients to understand the condition of surrounding built environment of an area where they would decide to live.

Moreover, during the planning process, urban planners and transportation planners together can plan for residential areas with reduced transportation lands and reduced traffic speed yet with enhanced mobility for the residents. With the help of local government, transportation planners and urban planners can ensure the residential locations at safer distance from the major highways, also for existing residential areas near highways there should be sufficient protective measures such as green boundaries. Green boundaries or vegetation buffer can help sequester vehicle emitted as well as traffic infrastructure related air pollutants. Such initiatives can help to reduce adult asthma hospitalization rate and can improve the traffic environment as well as provide healthy built environment for the asthmatic and other people.

9.4 Recommendations regarding dwelling parameters

Healthy indoor environment is important to ensure because people spend most of their time in there. My research data indicates increase of housing units with incomplete kitchen and incomplete plumbing are strongly associated with increased adult asthma hospitalization rate. Moreover, dilapidated, or older housing units are also significantly related with the increased hospitalization rate. To predict the indoor air quality, fuel used for house heating was used as a proxy for cooking fuel because data on cooking fuel was not available. Except fuel oil or kerosene, all other types of house heating fuels were not associated with asthma exacerbation. Though kerosene was used by only a very small percent of people (0.06%) and the direction of the association with adult asthma hospitalization rate indicates that such fuel is not used in the households of those census block groups where adult asthma patients were living. It is to be assumed, the impact of using such fuels (kerosene, coal or wood) is well known among asthmatic people and they try to avoid using such fuels as precaution. Therefore, this region has overcame the negative impact of use of such fuels for indoor use.

Careful measures should be taken for other strong predictors. Substandard housings with incomplete kitchen and plumbing systems or dilapidated conditions should be renovated or upgraded according to the standard housing codes. Public health agencies and housing authorities should make strong collaborations to ensure enforcement of these codes. Historically, housing and building codes are results of public health reforms of the late 1800s and early 1900s to tackle infectious disease instigated by public housing. But today, housing and health departments are different sectors which obstructs their capabilities to undertake more comprehensive and place-based approach (De Leon, E., & Schilling 2017). Currently, preparation and execution of most housing codes are the responsibility of housing and construction department (Krieger and Higgins 2002). Through strong cooperation among public health, housing, and urban planning department, it is important to ensure healthy homes. Local governments can promote community outreach to educate housing authorities and residents to resolve complex issues of substandard housing.

9.5 Recommendations regarding air pollutants

The information of air pollutants was available at county level. Concentration of ozone (ppm) and concentration of PM 2.5 (μg/m^3) were considered in the research model. The ozone concentration variables was insignificant at $p < 0.10$ level but PM 2.5 concentration was statistically significant in the model output. concentration of ozone was inversely related with adult asthma hospitalization rate on the other hand PM 2.5 concentration was positively related to adult asthma hospitalization at census block group level. This is indicating, with the increased concentration of $PM_{2.5}$ in counties, the adult asthma hospitalization in pertinent census block groups would also increase. Urban planners should employ pollution reduction techniques in different areas to keep the concentration of $PM_{2.5}$ in manageable limit. Moreover, trees help to absorb or reduce particulate matters to be suspended in the air. Increased vegetation and tree plantation in different areas can help reducing such pollutant. Moreover, since transportation related infrastructure and combustion in vehicles are major sources of PM2.5, therefore diesel/gasoline/fossil fuel emission reduction can be introduced. Or in other words, diesel or fossil fuel powered engines and equipment can be replaced with more environmental friendly alternatives.

There are multiple number of ozone monitoring stations in north central Texas region. Moreover, there is ozone alert system for bad ozone days ranging from high alert levels (maroon color- indicate hazardous) to lower alert level (green color-indicate good). An ozone alert is issued every time the ozone level increases (orange level, more than 71 ppb) that is harmful for sensitive group of people like children, elderly with respiratory health issues and workers who work outside for a long time. During an Ozone Alert Day, the sensitive groups are advised to reduce prolonged outside activities and people with asthma are advised to follow their asthma action plan and keep their relief medicine handy (City of Dallas 2018). The negative coefficient of ozone concentration with asthma hospitalization is an indication about public awareness regarding bad ozone days. “Bad ozone day” alert system helps people to take cautious measures therefore asthma hospitalization rates do not increase with the increase of ozone concentration in the county.

Such warning system can also be introduced for other pollutants. This may help asthmatic vulnerable group of people to be cautious and avoid exposure to such pollutants.

Chapter 10 Conclusion

Understanding the influence of built environmental variables of both indoor and outdoor becomes a complex challenge for urban planners, policy makers and public health agencies since they are responsible for the development and execution of policies and strategies to provide safe environment for vulnerable asthmatic people. Inter-governmental as well as inter-departmental collaboration may play an important role in the development of integrated asthma mitigation policies. The concerning bodies on this policy making process may vary from state department of housing, transportation or planning to local government, metropolitan planning organization, local housing authorities as well as transit agencies. Since the results of my study provide strong indication about correlation between asthma exacerbation and distressed socioeconomic conditions, therefore, it would be very efficient if asthma mitigation strategies are incorporated into environmental justice policies.

The findings of this research can be thoughtfully envisioned by public health researchers and practitioners that they can consider for remedial of asthma exacerbation. This research can help Policy makers and executers to understand the geographic as well as demographic factors behind asthma severity and hence can support the remedial efforts with relevant urban planning techniques. Moreover, urban planners should be considered as an extension of public health workforce, as planners can collaborate and help public health department in many ways. Such as, through map creation, identifying clusters, identification of potential spatial parameters, depicting health disparities and providing innovative solutions to the problems. My research can be an example for such initiatives. In this way, this research can contribute to the field of urban planning, health, and public welfare policies.

Besides such scope of inter-disciplinary collaborations, my research also explored several future research scopes. Those future research scopes can be considered as follow:

Future research scopes:

- There can be detail analysis on asthma and individual land use types. Such as, detail exploration about the condition of vacant lands in different areas and how they are affecting asthma condition in different neighborhoods can be analyzed. For this, a detail inventory on vacant land can be developed indicating whether they are covered with weeds or wastes are disposed on those sites. This can bring a new insight about the land use type and public health scenario in this region.
- My research identified a strong and negative association between CBG level travel time to work and adult asthma hospitalization. It is assumed that adult asthmatic patients avoid longer travel time to work considering their health condition. A survey or focus group discussion could explain the reason behind such inverse relationship. Future research can consider inclusion of detail survey on asthmatic patients regarding their travel pattern to understand how travel patterns can influence asthma exacerbation. It can include but not limited to travel time, origin destination, travel purposes, and travel modes used.
- Though the American Housing Survey has information on several indoor environmental qualities such as presence of vermin, types of cooking fuel used, smoking – but for Dallas Fort Worth metro region, only 2000 records were found which is very low than the number of patient cases of my study also lower than the number of census block groups where those asthma patients are living. AHS information is thus not sufficient for my research. Therefore, I could not use the data of vermin, cooking fuel or other indoor related information. A survey regarding indoor environment quality and detail

analysis can also be interesting. Such in depth studies can contribute to the understanding of adult asthma condition with respect to indoor environment for north central Texas region.

- Besides above-mentioned scopes, future research can account for other limitations of my research. Such as my research did not have access to the information about weight, height, living style, stress level, or genetic information of the patients. By collecting and incorporating this information in research, future studies can provide more enriched information and also can identify the authentic reason behind some patterns such as why adult female asthmatic patients are the most vulnerable in this region.

Appendix

Pearson Correlation Coefficient table for adult asthma hospitalization rate and land use variables

Correlations

		LnHospRate	medHH_Inc	Edu_25Ndip	Rac_white	Rac_black	ProportionAirport	Cemeteries	Commercial	Communication	Education	Farmland	Flood control	Group quarters	Hotel/motel	Improved acreage	Industrial	Institutional/semi-public	Landfill	Large stadium	Mixed use	Mobile home	Multi-family	Office	Parking	Parks/recreation	Railroad	Ranch land	Residential acreage	Retail	Runway	Single family	Small water bodies	Timberland	Transit	Under construction	Utilities	Vacant	Water
LnHospRate	Pearson Correlation	1	-.453**	.016	-.426**	.213**	.002	-.009	.130**	.024	.002	-.085**	.029	-.024	.000	-.068**	.060**	.080**	-.002	-.004	-.013	.024	.111**	-.020	-.001	-.053**	.089**	-.084**	-.122**	-.011	-.003	-.077**	-.079**	-.083**	.044*	-.031	.035*	.182**	-.062**
	Sig. (2-tailed)		.000	.371	.000	.000	.928	.601	.000	.174	.901	.000	.096	.174	.982	.000	.001	.000	.889	.802	.467	.171	.000	.255	.948	.002	.000	.000	.000	.545	.849	.000	.000	.000	.012	.079	.045	.000	.000
	N	3292	3292	3292	3292	3292	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265	3265
medHH_Inc	Pearson Correlation	-.453**	1	-.108**	.372**	-.160**	-.024	-.054**	-.216**	-.012	-.036*	.098**	-.029	-.071**	-.041*	.060**	-.094**	-.129**	-.020	-.020	-.003	-.042*	-.282**	-.003	-.058**	.104**	-.101**	.079**	.095**	-.045*	-.040*	.232**	.141**	.021	-.081**	.011	-.037*	-.137**	.089**
	Sig. (2-tailed)	.000		.000	.000	.000	.168	.002	.000	.505	.040	.000	.099	.000	.018	.001	.000	.000	.263	.261	.859	.016	.000	.863	.001	.000	.000	.000	.000	.010	.021	.000	.000	.221	.000	.538	.035	.000	.000
	N	3292	3296	3296	3296	3296	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Edu_25Ndip	Pearson Correlation	.016	-.108**	1	.200**	.212**	.008	-.012	-.016	.008	-.001	-.020	.033	.011	-.009	-.024	.013	.002	.056**	.017	.016	.041*	-.031	-.035*	-.040*	.019	-.004	.031	.020	-.028	.023	-.036*	-.011	.009	-.008	-.015	.011	.058**	.037*
	Sig. (2-tailed)	.371	.000		.000	.000	.651	.497	.371	.662	.970	.261	.063	.522	.614	.177	.457	.913	.001	.334	.362	.020	.076	.045	.022	.285	.835	.081	.258	.113	.179	.037	.534	.626	.643	.407	.515	.001	.034
	N	3292	3296	3296	3296	3296	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Rac_white	Pearson Correlation	-.426**	.372**	.200**	1	-.064**	-.009	-.032	-.188**	-.003	-.010	.163**	-.011	-.004	-.042*	.116**	-.030	-.104**	.027	-.011	-.005	.150**	-.188**	-.012	-.038*	.023	-.072**	.254**	.282**	-.055**	-.022	-.045*	.063**	.118**	-.076**	.027	-.025	-.065**	.111**
	Sig. (2-tailed)	.000	.000	.000		.000	.614	.068	.000	.884	.582	.000	.511	.824	.016	.000	.085	.000	.118	.527	.756	.000	.000	.476	.030	.188	.000	.000	.000	.002	.204	.010	.000	.000	.000	.122	.159	.000	.000
	N	3292	3296	3296	3296	3296	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Rac_black	Pearson Correlation	.213**	-.160**	.212**	-.064**	1	.032	-.004	-.007	-.002	.011	-.051**	.055**	-.001	.011	-.050**	.019	.031	.019	-.016	-.018	-.050**	.120**	-.021	.004	.045*	-.016	-.062**	-.127**	-.017	.027	-.110**	-.024	.012	-.015	.006	.075**	.250**	-.038*
	Sig. (2-tailed)	.000	.000	.000	.000		.066	.823	.698	.907	.548	.003	.002	.966	.532	.004	.276	.074	.276	.349	.308	.004	.000	.231	.836	.011	.358	.000	.000	.337	.130	.000	.165	.488	.377	.732	.000	.000	.030
	N	3292	3296	3296	3296	3296	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
ProportionAirport	Pearson Correlation	.002	-.024	.008	-.009	.032	1	-.004	.014	-.003	-.016	.015	-.005	-.010	.013	.005	.067**	.002	-.004	.045**	-.002	-.009	-.021	-.008	-.001	-.021	-.007	.032	.036*	-.008	.458**	-.076**	-.007	.018	.007	.006	.002	.004	.017
	Sig. (2-tailed)	.928	.168	.651	.614	.066		.799	.420	.873	.362	.386	.783	.578	.457	.777	.000	.925	.821	.009	.922	.623	.239	.629	.965	.237	.692	.070	.041	.656	.000	.000	.697	.310	.691	.723	.921	.804	.318
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Cemeteries	Pearson Correlation	-.009	-.054**	-.012	-.032	-.004	-.004	1	-.001	-.005	-.027	-.012	-.008	.011	-.012	.031	.010	.006	-.001	-.007	-.003	-.011	-.004	.012	-.006	.002	.015	-.023	-.011	-.009	-.006	-.055**	-.008	.010	.009	-.003	-.007	-.007	-.011
	Sig. (2-tailed)	.601	.002	.497	.068	.823	.799		.959	.797	.128	.494	.648	.540	.489	.080	.549	.727	.938	.707	.858	.518	.815	.485	.730	.891	.403	.198	.532	.602	.733	.002	.653	.575	.597	.865	.696	.687	.536
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Commercial	Pearson Correlation	.130**	-.216**	-.016	-.188**	-.007	.014	-.001	1	.044*	-.041*	-.100**	-.001	.083**	.220**	-.053**	.186**	.134**	-.024	.005	.063**	-.032	.098**	.124**	.109**	-.132**	.112**	-.210**	-.204**	.132**	-.001	-.263**	-.083**	-.086**	.127**	.019	.018	.087**	-.121**
	Sig. (2-tailed)	.000	.000	.371	.000	.698	.420	.959		.012	.019	.000	.932	.000	.000	.002	.000	.000	.175	.756	.000	.067	.000	.000	.000	.000	.000	.000	.000	.000	.973	.000	.000	.000	.000	.290	.304	.000	.000
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Communication	Pearson Correlation	.024	-.012	.008	-.003	-.002	-.003	-.005	.044*	1	.030	-.018	-.008	-.001	-.002	-.008	.023	.004	-.003	.005	-.003	-.016	-.010	.007	.024	.021	.018	-.023	-.031	.027	-.005	-.031	-.022	-.010	.001	.005	.008	.027	-.010
	Sig. (2-tailed)	.174	.505	.662	.884	.907	.873	.797	.012		.087	.312	.644	.952	.907	.653	.197	.822	.867	.772	.846	.347	.559	.681	.179	.237	.294	.191	.080	.121	.784	.078	.205	.577	.973	.781	.654	.127	.560
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Education	Pearson Correlation	.002	-.036*	-.001	-.010	.011	-.016	-.027	-.041*	.030	1	-.037*	-.029	.030	-.040*	-.029	-.038*	.062**	-.015	.029	.003	-.048**	-.050**	-.030	.031	.010	-.027	-.108**	-.100**	-.021	-.019	-.021	-.065**	-.040*	-.016	-.023	-.035*	-.063**	-.072**
	Sig. (2-tailed)	.901	.040	.970	.582	.548	.362	.128	.019	.087		.033	.101	.081	.021	.096	.032	.000	.386	.097	.884	.006	.004	.085	.077	.572	.128	.000	.000	.223	.281	.222	.000	.022	.375	.179	.048	.000	.000
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Farmland	Pearson Correlation	-.085**	.098**	-.020	.163**	-.051**	.015	-.012	-.100**	-.018	-.037*	1	-.014	-.024	-.023	.299**	.010	-.048**	-.009	-.008	-.006	.055**	-.085**	-.026	-.020	-.048**	-.029	.058**	.230**	-.050**	.016	-.171**	.007	.064**	-.017	.016	-.016	-.056**	.009
	Sig. (2-tailed)	.000	.000	.261	.000	.003	.386	.494	.000	.312	.033		.413	.162	.195	.000	.571	.006	.589	.662	.728	.002	.000	.143	.262	.006	.101	.001	.000	.004	.372	.000	.685	.000	.343	.352	.346	.001	.597
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Flood control	Pearson Correlation	.029	-.029	.033	-.011	.055**	-.005	-.008	-.001	-.008	-.029	-.014	1	-.010	.002	-.015	.062**	-.017	.023	-.006	-.003	-.010	-.029	-.009	-.007	.022	-.002	-.028	-.026	-.018	-.005	-.083**	.111**	.001	-.008	.006	.021	.011	.020
	Sig. (2-tailed)	.096	.099	.063	.511	.002	.783	.648	.932	.644	.101	.413		.581	.900	.387	.000	.329	.188	.753	.886	.570	.099	.621	.670	.214	.899	.116	.142	.306	.784	.000	.000	.958	.665	.711	.235	.545	.265
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Group quarters	Pearson Correlation	-.024	-.071**	.011	-.004	-.001	-.010	.011	.083**	-.001	.030	-.024	-.010	1	.014	-.002	-.024	.058**	-.009	.046**	-.005	-.018	.013	.055**	.065**	-.017	-.008	-.043*	-.046**	.082**	-.006	-.051**	-.021	-.026	-.010	-.005	.013	.009	-.030
	Sig. (2-tailed)	.174	.000	.522	.824	.966	.578	.540	.000	.952	.081	.162	.581		.426	.897	.165	.001	.617	.008	.764	.295	.440	.002	.000	.334	.651	.013	.009	.000	.722	.004	.239	.142	.560	.769	.474	.617	.085
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Hotel/motel	Pearson Correlation	.000	-.041*	-.009	-.042*	.011	.013	-.012	.220**	-.002	-.040*	-.023	.002	.014	1	-.028	.007	.054**	-.008	.000	.075**	-.019	.094**	.078**	.084**	-.024	.014	-.059**	-.055**	.128**	-.004	-.159**	.032	-.027	.062**	.008	.032	.074**	-.021
	Sig. (2-tailed)	.982	.018	.614	.016	.532	.457	.489	.000	.907	.021	.195	.900	.426		.109	.684	.002	.629	.986	.000	.271	.000	.000	.000	.168	.410	.001	.002	.000	.818	.000	.064	.124	.000	.652	.064	.000	.239
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Improved acreage	Pearson Correlation	-.068**	.060**	-.024	.116**	-.050**	.005	.031	-.053**	-.008	-.029	.299**	-.015	-.002	-.028	1	.025	-.023	.009	-.008	-.006	.037*	-.086**	-.014	.016	-.020	-.014	.088**	.217**	-.033	.000	-.109**	.016	.177**	-.018	-.010	-.023	-.018	.022
	Sig. (2-tailed)	.000	.001	.177	.000	.004	.777	.080	.002	.653	.096	.000	.387	.897	.109		.152	.197	.608	.643	.713	.035	.000	.440	.360	.247	.432	.000	.000	.061	.977	.000	.375	.000	.313	.568	.190	.317	.208
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Industrial	Pearson Correlation	.060**	-.094**	.013	-.030	.019	.067**	.010	.186**	.023	-.038*	.010	.062**	-.024	.007	.025	1	.018	.037*	.017	.001	.005	-.082**	.002	.053**	-.029	.151**	-.001	-.036*	-.031	.067**	-.244**	.020	.013	.090**	.016	.024	.107**	-.025
	Sig. (2-tailed)	.001	.000	.457	.085	.276	.000	.549	.000	.197	.032	.571	.000	.165	.684	.152		.310	.036	.341	.942	.797	.000	.893	.002	.093	.000	.932	.037	.075	.000	.000	.248	.459	.000	.357	.179	.000	.148
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Institutional/semi-public	Pearson Correlation	.080**	-.129**	.002	-.104**	.031	.002	.006	.134**	.004	.062**	-.048**	-.017	.058**	.054**	-.023	.018	1	-.020	.007	.021	-.068**	-.028	.048**	.110**	-.074**	.035*	-.142**	-.118**	.010	-.013	-.041*	-.061**	-.044*	.032	.002	-.015	.022	-.082**
	Sig. (2-tailed)	.000	.000	.913	.000	.074	.925	.727	.000	.822	.000	.006	.329	.001	.002	.197	.310		.264	.700	.230	.000	.112	.006	.000	.000	.044	.000	.000	.568	.464	.020	.001	.012	.068	.896	.406	.214	.000
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Landfill	Pearson Correlation	-.002	-.020	.056**	.027	.019	-.004	-.001	-.024	-.003	-.015	-.009	.023	-.009	-.008	.009	.037*	-.020	1	-.004	-.002	.013	-.031	-.009	-.004	.070**	.004	.002	.012	-.016	-.004	-.073**	.136**	.006	-.006	.002	.046**	.019	.012
	Sig. (2-tailed)	.889	.263	.001	.118	.276	.821	.938	.175	.867	.386	.589	.188	.617	.629	.608	.036	.264		.797	.907	.443	.073	.604	.835	.000	.815	.908	.486	.362	.831	.000	.000	.723	.730	.889	.009	.269	.489
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Large stadium	Pearson Correlation	-.004	-.020	.017	-.011	-.016	.045**	-.007	.005	.005	.029	-.008	-.006	.046**	.000	-.008	.017	.007	-.004	1	-.002	-.008	-.002	.001	.156**	.010	.007	-.011	-.010	.001	.001	-.041*	-.009	.013	.000	.005	-.002	-.005	-.012
	Sig. (2-tailed)	.802	.261	.334	.527	.349	.009	.707	.756	.772	.097	.662	.753	.008	.986	.643	.341	.700	.797		.911	.635	.917	.965	.000	.565	.683	.543	.573	.944	.957	.019	.624	.444	.995	.786	.896	.777	.478
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Mixed use	Pearson Correlation	-.013	-.003	.016	-.005	-.018	-.002	-.003	.063**	-.003	.003	-.006	-.003	-.005	.075**	-.006	.001	.021	-.002	-.002	1	-.006	.014	.050**	-.002	-.012	-.003	-.012	-.010	.027	-.002	-.031	-.010	-.005	-.004	.006	-.009	.003	-.005
	Sig. (2-tailed)	.467	.859	.362	.756	.308	.922	.858	.000	.846	.884	.728	.886	.764	.000	.713	.942	.230	.907	.911		.736	.413	.004	.904	.476	.875	.507	.570	.116	.920	.072	.579	.780	.820	.748	.620	.882	.786
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Mobile home	Pearson Correlation	.024	-.042*	.041*	.150**	-.050**	-.009	-.011	-.032	-.016	-.048**	.055**	-.010	-.018	-.019	.037*	.005	-.068**	.013	-.008	-.006	1	-.080**	-.025	-.021	-.060**	-.013	.164**	.144**	-.046**	-.007	-.145**	.050**	.030	.010	-.009	-.007	.027	.023
	Sig. (2-tailed)	.171	.016	.020	.000	.004	.623	.518	.067	.347	.006	.002	.570	.295	.271	.035	.797	.000	.443	.635	.736		.000	.154	.224	.001	.455	.000	.000	.009	.693	.000	.004	.081	.563	.614	.675	.118	.182
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Multi-family	Pearson Correlation	.111**	-.282**	-.031	-.188**	.120**	-.021	-.004	.098**	-.010	-.050**	-.085**	-.029	.013	.094**	-.086**	-.082**	-.028	-.031	-.002	.014	-.080**	1	.032	.028	-.075**	-.043*	-.182**	-.157**	.097**	-.022	-.388**	-.021	-.058**	.041*	-.013	-.003	-.098**	-.087**
	Sig. (2-tailed)	.000	.000	.076	.000	.000	.239	.815	.000	.559	.004	.000	.099	.440	.000	.000	.000	.112	.073	.917	.413	.000		.064	.114	.000	.013	.000	.000	.000	.208	.000	.235	.001	.020	.463	.855	.000	.000
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Office	Pearson Correlation	-.020	-.003	-.035*	-.012	-.021	-.008	.012	.124**	.007	-.030	-.026	-.009	.055**	.078**	-.014	.002	.048**	-.009	.001	.050**	-.025	.032	1	.042*	-.012	.035*	-.046**	-.044*	.074**	-.003	-.066**	-.002	-.021	-.006	.003	.013	.000	-.021
	Sig. (2-tailed)	.255	.863	.045	.476	.231	.629	.485	.000	.681	.085	.143	.621	.002	.000	.440	.893	.006	.604	.965	.004	.154	.064		.016	.488	.047	.008	.011	.000	.871	.000	.928	.238	.731	.875	.444	.996	.229
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Parking	Pearson Correlation	-.001	-.058**	-.040*	-.038*	.004	-.001	-.006	.109**	.024	.031	-.020	-.007	.065**	.084**	.016	.053**	.110**	-.004	.156**	-.002	-.021	.028	.042*	1	.009	.026	-.045*	-.037*	.023	-.007	-.113**	-.026	-.018	.043*	.028	-.006	.009	-.022
	Sig. (2-tailed)	.948	.001	.022	.030	.836	.965	.730	.000	.179	.077	.262	.670	.000	.000	.360	.002	.000	.835	.000	.904	.224	.114	.016		.626	.137	.011	.033	.195	.695	.000	.131	.316	.014	.105	.719	.620	.212
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Parks/recreation	Pearson Correlation	-.053**	.104**	.019	.023	.045*	-.021	.002	-.132**	.021	.010	-.048**	.022	-.017	-.024	-.020	-.029	-.074**	.070**	.010	-.012	-.060**	-.075**	-.012	.009	1	-.002	-.131**	-.112**	-.044*	-.024	-.178**	.235**	-.020	.009	.004	.010	-.078**	.128**
	Sig. (2-tailed)	.002	.000	.285	.188	.011	.237	.891	.000	.237	.572	.006	.214	.334	.168	.247	.093	.000	.000	.565	.476	.001	.000	.488	.626		.918	.000	.000	.012	.172	.000	.000	.255	.594	.808	.580	.000	.000
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Railroad	Pearson Correlation	.089**	-.101**	-.004	-.072**	-.016	-.007	.015	.112**	.018	-.027	-.029	-.002	-.008	.014	-.014	.151**	.035*	.004	.007	-.003	-.013	-.043*	.035*	.026	-.002	1	-.035*	-.065**	-.032	-.009	-.091**	-.009	-.026	.060**	-.005	.031	.080**	-.019
	Sig. (2-tailed)	.000	.000	.835	.000	.358	.692	.403	.000	.294	.128	.101	.899	.651	.410	.432	.000	.044	.815	.683	.875	.455	.013	.047	.137	.918		.045	.000	.067	.590	.000	.624	.135	.001	.771	.081	.000	.273
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Ranch land	Pearson Correlation	-.084**	.079**	.031	.254**	-.062**	.032	-.023	-.210**	-.023	-.108**	.058**	-.028	-.043*	-.059**	.088**	-.001	-.142**	.002	-.011	-.012	.164**	-.182**	-.046**	-.045*	-.131**	-.035*	1	.531**	-.081**	-.006	-.358**	.078**	.128**	-.048**	-.013	-.030	-.044*	.006
	Sig. (2-tailed)	.000	.000	.081	.000	.000	.070	.198	.000	.191	.000	.001	.116	.013	.001	.000	.932	.000	.908	.543	.507	.000	.000	.008	.011	.000	.045		.000	.000	.722	.000	.000	.000	.006	.379	.092	.013	.722
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Residential acreage	Pearson Correlation	-.122**	.095**	.020	.282**	-.127**	.036*	-.011	-.204**	-.031	-.100**	.230**	-.026	-.046**	-.055**	.217**	-.036*	-.118**	.012	-.010	-.010	.144**	-.157**	-.044*	-.037*	-.112**	-.065**	.531**	1	-.076**	-.003	-.286**	.068**	.189**	-.038*	-.019	-.046**	-.039*	.039*
	Sig. (2-tailed)	.000	.000	.258	.000	.000	.041	.532	.000	.080	.000	.000	.142	.009	.002	.000	.037	.000	.486	.573	.570	.000	.000	.011	.033	.000	.000	.000		.000	.868	.000	.000	.000	.029	.282	.008	.028	.024
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Retail	Pearson Correlation	-.011	-.045*	-.028	-.055**	-.017	-.008	-.009	.132**	.027	-.021	-.050**	-.018	.082**	.128**	-.033	-.031	.010	-.016	.001	.027	-.046**	.097**	.074**	.023	-.044*	-.032	-.081**	-.076**	1	-.001	-.128**	-.032	-.034	.021	.019	.006	-.023	-.045*
	Sig. (2-tailed)	.545	.010	.113	.002	.337	.656	.602	.000	.121	.223	.004	.306	.000	.000	.061	.075	.568	.362	.944	.116	.009	.000	.000	.195	.012	.067	.000	.000		.959	.000	.065	.050	.220	.279	.722	.193	.010
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Runway	Pearson Correlation	-.003	-.040*	.023	-.022	.027	.458**	-.006	-.001	-.005	-.019	.016	-.005	-.006	-.004	.000	.067**	-.013	-.004	.001	-.002	-.007	-.022	-.003	-.007	-.024	-.009	-.006	-.003	-.001	1	-.073**	-.014	-.005	-.001	.002	.003	.037*	.017
	Sig. (2-tailed)	.849	.021	.179	.204	.130	.000	.733	.973	.784	.281	.372	.784	.722	.818	.977	.000	.464	.831	.957	.920	.693	.208	.871	.695	.172	.590	.722	.868	.959		.000	.437	.754	.939	.907	.886	.034	.323
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Single family	Pearson Correlation	-.077**	.232**	-.036*	-.045*	-.110**	-.076**	-.055**	-.263**	-.031	-.021	-.171**	-.083**	-.051**	-.159**	-.109**	-.244**	-.041*	-.073**	-.041*	-.031	-.145**	-.388**	-.066**	-.113**	-.178**	-.091**	-.358**	-.286**	-.128**	-.073**	1	-.140**	-.135**	-.118**	-.030	-.096**	-.262**	-.191**
	Sig. (2-tailed)	.000	.000	.037	.010	.000	.000	.002	.000	.078	.222	.000	.000	.004	.000	.000	.000	.020	.000	.019	.072	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.086	.000	.000	.000
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Small water bodies	Pearson Correlation	-.079**	.141**	-.011	.063**	-.024	-.007	-.008	-.083**	-.022	-.065**	.007	.111**	-.021	.032	.016	.020	-.061**	.136**	-.009	-.010	.050**	-.021	-.002	-.026	.235**	-.009	.078**	.068**	-.032	-.014	-.140**	1	.018	-.025	-.010	.014	.007	.017
	Sig. (2-tailed)	.000	.000	.534	.000	.165	.697	.653	.000	.205	.000	.685	.000	.239	.064	.375	.248	.001	.000	.624	.579	.004	.235	.928	.131	.000	.624	.000	.000	.065	.437	.000		.310	.151	.583	.409	.682	.324
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Timberland	Pearson Correlation	-.083**	.021	.009	.118**	.012	.018	.010	-.086**	-.010	-.040*	.064**	.001	-.026	-.027	.177**	.013	-.044*	.006	.013	-.005	.030	-.058**	-.021	-.018	-.020	-.026	.128**	.189**	-.034	-.005	-.135**	.018	1	-.009	-.001	.022	-.022	.114**
	Sig. (2-tailed)	.000	.221	.626	.000	.488	.310	.575	.000	.577	.022	.000	.958	.142	.124	.000	.459	.012	.723	.444	.780	.081	.001	.238	.316	.255	.135	.000	.000	.050	.754	.000	.310		.618	.939	.218	.217	.000
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Transit	Pearson Correlation	.044*	-.081**	-.008	-.076**	-.015	.007	.009	.127**	.001	-.016	-.017	-.008	-.010	.062**	-.018	.090**	.032	-.006	.000	-.004	.010	.041*	-.006	.043*	.009	.060**	-.048**	-.038*	.021	-.001	-.118**	-.025	-.009	1	.004	.034	.030	-.015
	Sig. (2-tailed)	.012	.000	.643	.000	.377	.691	.597	.000	.973	.375	.343	.665	.560	.000	.313	.000	.068	.730	.995	.820	.563	.020	.731	.014	.594	.001	.006	.029	.220	.939	.000	.151	.618		.824	.050	.086	.380
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Under construction	Pearson Correlation	-.031	.011	-.015	.027	.006	.006	-.003	.019	.005	-.023	.016	.006	-.005	.008	-.010	.016	.002	.002	.005	.006	-.009	-.013	.003	.028	.004	-.005	-.015	-.019	.019	.002	-.030	-.010	-.001	.004	1	.001	.022	-.004
	Sig. (2-tailed)	.079	.538	.407	.122	.732	.723	.865	.290	.781	.179	.352	.711	.769	.652	.568	.357	.896	.889	.786	.748	.614	.463	.875	.105	.808	.771	.379	.282	.279	.907	.086	.583	.939	.824		.933	.200	.821
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Utilities	Pearson Correlation	.035*	-.037*	.011	-.025	.075**	.002	-.007	.018	.008	-.035*	-.016	.021	.013	.032	-.023	.024	-.015	.046**	-.002	-.009	-.007	-.003	.013	-.006	.010	.031	-.030	-.046**	.006	.003	-.096**	.014	.022	.034	.001	1	.077**	.031
	Sig. (2-tailed)	.045	.035	.515	.159	.000	.921	.696	.304	.654	.048	.346	.235	.474	.064	.190	.179	.406	.009	.896	.620	.675	.855	.444	.719	.580	.081	.092	.008	.722	.886	.000	.409	.218	.050	.933		.000	.080
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Vacant	Pearson Correlation	.182**	-.137**	.058**	-.065**	.250**	.004	-.007	.087**	.027	-.063**	-.056**	.011	.009	.074**	-.018	.107**	.022	.019	-.005	.003	.027	-.098**	.000	.009	-.078**	.080**	-.044*	-.039*	-.023	.037*	-.262**	.007	-.022	.030	.022	.077**	1	-.047**
	Sig. (2-tailed)	.000	.000	.001	.000	.000	.804	.687	.000	.127	.000	.001	.545	.617	.000	.317	.000	.214	.269	.777	.882	.118	.000	.996	.620	.000	.000	.013	.028	.193	.034	.000	.682	.217	.086	.200	.000		.007
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
Water	Pearson Correlation	-.062**	.089**	.037*	.111**	-.038*	.017	-.011	-.121**	-.010	-.072**	.009	.020	-.030	-.021	.022	-.025	-.082**	.012	-.012	-.005	.023	-.087**	-.021	-.022	.128**	-.019	.006	.039*	-.045*	.017	-.191**	.017	.114**	-.015	-.004	.031	-.047**	1
	Sig. (2-tailed)	.000	.000	.034	.000	.030	.318	.536	.000	.560	.000	.597	.265	.085	.239	.208	.148	.000	.489	.478	.786	.182	.000	.229	.212	.000	.273	.722	.024	.010	.323	.000	.324	.000	.380	.821	.080	.007	
	N	3265	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269

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

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

Pearson Correlation Coefficient table for adult asthma hospitalization rate and transportation variables

Correlations

		LnHospRate	WEIGHTEDDensityROAD	tot_Ttim	Ttim_Lss5	Ttim_5_9mn	Ttim_10_14	Ttim_15_19	Ttim_20_24	Ttim_25_29	Ttim_30_34	Ttim_35_39	Ttim_40_44	Ttim_45_59	Ttim_60_89	Ttim_90mor	WghtdAvgSpeed	inHafMIL_C	inQrtMIL_C	in1MIL_C
LnHospRate	Pearson Correlation	1	.084**	-.355**	-.139**	-.221**	-.235**	-.222**	-.240**	-.235**	-.235**	-.204**	-.248**	-.258**	-.174**	-.103**	.092**	.173**	.148**	.182**
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	3288	3288	3288	3288	3288	3288	3288	3288	3288	3288	3288	3288	3288	3288	3288	3288	3288	3288	3288
WEIGHTEDDensityROAD	Pearson Correlation	.084**	1	-.165**	-.091**	-.038*	-.005	-.021	-.041*	-.042*	-.111**	-.143**	-.139**	-.247**	-.271**	-.206**	.214**	.200**	.192**	.212**
	Sig. (2-tailed)	.000		.000	.000	.029	.795	.218	.020	.015	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	3288	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
tot_Ttim	Pearson Correlation	-.355**	-.165**	1	.283**	.466**	.622**	.649**	.716**	.626**	.772**	.539**	.605**	.716**	.584**	.344**	-.034	-.149**	-.130**	-.174**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.052	.000	.000	.000
	N	3288	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
Ttim_Lss5	Pearson Correlation	-.139**	-.091**	.283**	1	.285**	.206**	.150**	.114**	.120**	.101**	.128**	.112**	.151**	.125**	.110**	-.025	.006	-.042*	-.013
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.156	.731	.016	.444
	N	3288	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
Ttim_5_9mn	Pearson Correlation	-.221**	-.038*	.466**	.285**	1	.409**	.282**	.255**	.188**	.200**	.148**	.160**	.184**	.134**	.112**	.062**	.052**	-.012	.045**
	Sig. (2-tailed)	.000	.029	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.003	.479	.009
	N	3288	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
Ttim_10_14	Pearson Correlation	-.235**	-.005	.622**	.206**	.409**	1	.456**	.408**	.303**	.328**	.205**	.261**	.265**	.195**	.134**	.065**	.010	-.009	.020
	Sig. (2-tailed)	.000	.795	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.586	.593	.254
	N	3288	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
Ttim_15_19	Pearson Correlation	-.222**	-.021	.649**	.150**	.282**	.456**	1	.453**	.355**	.412**	.234**	.270**	.283**	.198**	.147**	.066**	-.009	-.025	-.032
	Sig. (2-tailed)	.000	.218	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.620	.155	.070
	N	3288	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
Ttim_20_24	Pearson Correlation	-.240**	-.041*	.716**	.114**	.255**	.408**	.453**	1	.465**	.495**	.324**	.343**	.370**	.280**	.162**	.024	-.088**	-.070**	-.076**
	Sig. (2-tailed)	.000	.020	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.161	.000	.000	.000
	N	3288	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
Ttim_25_29	Pearson Correlation	-.235**	-.042*	.626**	.120**	.188**	.303**	.355**	.465**	1	.448**	.323**	.371**	.395**	.295**	.157**	-.016	-.104**	-.072**	-.121**
	Sig. (2-tailed)	.000	.015	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.351	.000	.000	.000
	N	3288	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
Ttim_30_34	Pearson Correlation	-.235**	-.111**	.772**	.101**	.200**	.328**	.412**	.495**	.448**	1	.404**	.463**	.540**	.424**	.211**	-.041*	-.147**	-.120**	-.149**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.018	.000	.000	.000
	N	3288	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
Ttim_35_39	Pearson Correlation	-.204**	-.143**	.539**	.128**	.148**	.205**	.234**	.324**	.323**	.404**	1	.370**	.451**	.358**	.192**	-.064**	-.141**	-.096**	-.171**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000
	N	3288	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
Ttim_40_44	Pearson Correlation	-.248**	-.139**	.605**	.112**	.160**	.261**	.270**	.343**	.371**	.463**	.370**	1	.513**	.412**	.186**	-.075**	-.160**	-.124**	-.212**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000
	N	3288	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
Ttim_45_59	Pearson Correlation	-.258**	-.247**	.716**	.151**	.184**	.265**	.283**	.370**	.395**	.540**	.451**	.513**	1	.570**	.311**	-.130**	-.222**	-.175**	-.266**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000
	N	3288	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
Ttim_60_89	Pearson Correlation	-.174**	-.271**	.584**	.125**	.134**	.195**	.198**	.280**	.295**	.424**	.358**	.412**	.570**	1	.308**	-.139**	-.188**	-.139**	-.216**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000
	N	3288	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
Ttim_90mor	Pearson Correlation	-.103**	-.206**	.344**	.110**	.112**	.134**	.147**	.162**	.157**	.211**	.192**	.186**	.311**	.308**	1	-.086**	-.101**	-.069**	-.143**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000
	N	3288	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
WghtdAvgSpeed	Pearson Correlation	.092**	.214**	-.034	-.025	.062**	.065**	.066**	.024	-.016	-.041*	-.064**	-.075**	-.130**	-.139**	-.086**	1	.276**	.302**	.213**
	Sig. (2-tailed)	.000	.000	.052	.156	.000	.000	.000	.161	.351	.018	.000	.000	.000	.000	.000		.000	.000	.000
	N	3288	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
inHafMIL_C	Pearson Correlation	.173**	.200**	-.149**	.006	.052**	.010	-.009	-.088**	-.104**	-.147**	-.141**	-.160**	-.222**	-.188**	-.101**	.276**	1	.561**	.570**
	Sig. (2-tailed)	.000	.000	.000	.731	.003	.586	.620	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000
	N	3288	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
inQrtMIL_C	Pearson Correlation	.148**	.192**	-.130**	-.042*	-.012	-.009	-.025	-.070**	-.072**	-.120**	-.096**	-.124**	-.175**	-.139**	-.069**	.302**	.561**	1	.320**
	Sig. (2-tailed)	.000	.000	.000	.016	.479	.593	.155	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000
	N	3288	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
in1MIL_C	Pearson Correlation	.182**	.212**	-.174**	-.013	.045**	.020	-.032	-.076**	-.121**	-.149**	-.171**	-.212**	-.266**	-.216**	-.143**	.213**	.570**	.320**	1
	Sig. (2-tailed)	.000	.000	.000	.444	.009	.254	.070	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
	N	3288	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292

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

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

Pearson Correlation Coefficient table for adult asthma hospitalization rate and Dwelling condition variables

Correlations

		LnHospRate	prcntHheat_uTgs	prcntHheat_LPgs	prcntHheat_Elec	prcntHheat_Kero	prcntHheat_Coal	prcntHheat_Wood	prcntHheat_Sola	prcntHheat_Othr	prcntHheat_Nfue	prcntLak_Plumb	prcntLak_Kitchn	prct1979earlerBuilt
LnHospRate	Pearson Correlation	1	-.159**	-.112**	.085**	-.031	-.011	-.041*	.010	-.018	.038*	.170**	.159**	.292**
	Sig. (2-tailed)		.000	.000	.000	.073	.516	.019	.580	.311	.031	.000	.000	.000
	N	3292	3291	3291	3291	3291	3291	3291	3291	3291	3291	3291	3291	3291
prcntHheat_uTgs	Pearson Correlation	-.159**	1	-.230**	-.920**	-.024	-.011	-.105**	-.018	-.053**	-.115**	-.044*	-.060**	.275**
	Sig. (2-tailed)	.000		.000	0.000	.171	.544	.000	.293	.002	.000	.011	.001	.000
	N	3291	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
prcntHheat_LPgs	Pearson Correlation	-.112**	-.230**	1	.036*	.067**	-.010	.311**	.016	.157**	-.011	.069**	.065**	-.167**
	Sig. (2-tailed)	.000	.000		.040	.000	.574	.000	.361	.000	.528	.000	.000	.000
	N	3291	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
prcntHheat_Elec	Pearson Correlation	.085**	-.920**	.036*	1	-.010	-.001	.009	.004	.001	.082**	-.091**	-.085**	-.321**
	Sig. (2-tailed)	.000	0.000	.040		.554	.935	.611	.801	.973	.000	.000	.000	.000
	N	3291	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
prcntHheat_Kero	Pearson Correlation	-.031	-.024	.067**	-.010	1	-.004	-.004	-.005	.030	-.021	-.011	-.010	.010
	Sig. (2-tailed)	.073	.171	.000	.554		.825	.810	.758	.084	.228	.547	.569	.559
	N	3291	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
prcntHheat_Coal	Pearson Correlation	-.011	-.011	-.010	-.001	-.004	1	-.009	-.003	-.006	-.004	.029	.023	-.016
	Sig. (2-tailed)	.516	.544	.574	.935	.825		.586	.863	.710	.806	.100	.185	.348
	N	3291	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
prcntHheat_Wood	Pearson Correlation	-.041*	-.105**	.311**	.009	-.004	-.009	1	.017	.037*	.006	.025	.045**	-.041*
	Sig. (2-tailed)	.019	.000	.000	.611	.810	.586		.324	.034	.742	.147	.010	.019
	N	3291	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
prcntHheat_Sola	Pearson Correlation	.010	-.018	.016	.004	-.005	-.003	.017	1	-.006	-.002	-.012	-.007	-.004
	Sig. (2-tailed)	.580	.293	.361	.801	.758	.863	.324		.728	.927	.497	.697	.821
	N	3291	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
prcntHheat_Othr	Pearson Correlation	-.018	-.053**	.157**	.001	.030	-.006	.037*	-.006	1	-.017	.012	.002	-.050**
	Sig. (2-tailed)	.311	.002	.000	.973	.084	.710	.034	.728		.319	.501	.893	.004
	N	3291	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
prcntHheat_Nfue	Pearson Correlation	.038*	-.115**	-.011	.082**	-.021	-.004	.006	-.002	-.017	1	.016	.026	.018
	Sig. (2-tailed)	.031	.000	.528	.000	.228	.806	.742	.927	.319		.367	.143	.314
	N	3291	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
prcntLak_Plumb	Pearson Correlation	.170**	-.044*	.069**	-.091**	-.011	.029	.025	-.012	.012	.016	1	.541**	.149**
	Sig. (2-tailed)	.000	.011	.000	.000	.547	.100	.147	.497	.501	.367		.000	.000
	N	3291	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
prcntLak_Kitchn	Pearson Correlation	.159**	-.060**	.065**	-.085**	-.010	.023	.045**	-.007	.002	.026	.541**	1	.150**
	Sig. (2-tailed)	.000	.001	.000	.000	.569	.185	.010	.697	.893	.143	.000		.000
	N	3291	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292
prct1979earlerBuilt	Pearson Correlation	.292**	.275**	-.167**	-.321**	.010	-.016	-.041*	-.004	-.050**	.018	.149**	.150**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.559	.348	.019	.821	.004	.314	.000	.000	
	N	3291	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292	3292

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

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

- Outputs of Land Use and Adult Asthma Hospitalization Rate Linear Regression model 1

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.590[a]	.348	.340	.64876

a. Predictors: (Constant), Rac_Other, Rac_AmIndi, ProportionAirport, Flood control, Cemeteries, Under construction, Communication, Hotel/motel, Landfill, Group quarters, Railroad, Water, Improved acreage, Large stadium, Utilities, Mixed use, Mobile home, Rac_Asian, Transit, Rac_Hawai, Office, Education, Institutional/semi-public, Rac_black, Retail, Industrial, Timberland, Parking, Small water bodies, Multi-family, Farmland, Edu_25Ndip, Vacant, Parks/recreation, Ranch land, Commercial, Rac_white, Runway, Residential acreage, medHH_Inc

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	725.678	40	18.142	43.104	.000[b]
	Residual	1356.945	3224	.421		
	Total	2082.623	3264			

a. Dependent Variable: LnHospRate

b. Predictors: (Constant), Rac_Other, Rac_AmIndi, ProportionAirport, Flood control, Cemeteries, Under construction, Communication, Hotel/motel, Landfill, Group quarters, Railroad, Water, Improved acreage, Large stadium, Utilities, Mixed use, Mobile home, Rac_Asian, Transit, Rac_Hawai, Office, Education, Institutional/semi-public, Rac_black, Retail, Industrial, Timberland, Parking, Small water bodies, Multi-family, Farmland, Edu_25Ndip, Vacant, Parks/recreation, Ranch land, Commercial, Rac_white, Runway, Residential acreage, medHH_Inc

- Outputs of Land Use and Adult Asthma Hospitalization Rate Linear Regression model 2
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Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.587[a]	.345	.341	.64826

a. Predictors: (Constant), Multi-family, Cemeteries, Group quarters, Edu_25Ndip, Railroad, Timberland, Parks/recreation, Parking, Mobile home, Vacant, Industrial, Rac_Asian, Rac_Other, Commercial, Rac_black, Rac_white, medHH_Inc

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ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	718.097	17	42.241	100.516	.000[b]
	Residual	1364.526	3247	.420		
	Total	2082.623	3264			

a. Dependent Variable: LnHospRate

b. Predictors: (Constant), Multi-family, Cemeteries, Group quarters, Edu_25Ndip, Railroad, Timberland, Parks/recreation, Parking, Mobile home, Vacant, Industrial, Rac_Asian, Rac_Other, Commercial, Rac_black, Rac_white, medHH_Inc

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Out put of Linear Regression on Traffic Exposure and Asthma Hospitalization

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	in1MIL_C, Edu_25Ndip, Rac_Asian, Rac_black, WEIGHTEDDensityROAD, Rac_Other, WghtdAvgSpeed, Rac_white, medHH_Inc, inHafMIL_C, tot_Ttim[b]	.	Enter

a. Dependent Variable: LnHospRate

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.577[a]	.333	.330	.65340

a. Predictors: (Constant), in1MIL_C, Edu_25Ndip, Rac_Asian, Rac_black, WEIGHTEDDensityROAD, Rac_Other, WghtdAvgSpeed, Rac_white, medHH_Inc, inHafMIL_C, tot_Ttim

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	697.219	11	63.384	148.461	.000[b]
	Residual	1398.649	3276	.427		
	Total	2095.867	3287			

a. Dependent Variable: LnHospRate

b. Predictors: (Constant), in1MIL_C, Edu_25Ndip, Rac_Asian, Rac_black, WEIGHTEDDensityROAD, Rac_Other, WghtdAvgSpeed, Rac_white, medHH_Inc, inHafMIL_C, tot_Ttim

Output of Linear Regression on dwelling condition and Asthma Hospitalization

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.582[a]	.339	.335	.65102

a. Predictors: (Constant), All built 1979 or earlier, Hheat_Wood, Hheat_Coal, Hheat_Sola, Hheat_Kero, Hheat_Nfue, Hheat_Othr, Edu_25Ndip, Lak_Plumb, Hheat_uTgs, Rac_black, Rac_Other, Rac_Asian, Hheat_LPgs, Lak_Kitchn, Hheat_Elec, medHH_Inc, Rac_white

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	710.121	18	39.451	93.083	.000[b]
	Residual	1387.195	3273	.424		
	Total	2097.316	3291			

a. Dependent Variable: lnHospRate

b. Predictors: (Constant), All built 1979 or earlier, Hheat_Wood, Hheat_Coal, Hheat_Sola, Hheat_Kero, Hheat_Nfue, Hheat_Othr, Edu_25Ndip, Lak_Plumb, Hheat_uTgs, Rac_black, Rac_Other, Rac_Asian, Hheat_LPgs, Lak_Kitchn, Hheat_Elec, medHH_Inc, Rac_white

Final model:

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.581[a]	.337	.335	.65117

a. Predictors: (Constant), All built 1979 or earlier, Hheat_Elec, Hheat_Kero, Lak_Plumb, Hheat_uTgs, Hheat_LPgs, Edu_25Ndip, Rac_Other, Rac_Asian, Rac_black, Lak_Kitchn, medHH_Inc, Rac_white

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	707.382	13	54.414	128.329	.000[b]
	Residual	1389.934	3278	.424		
	Total	2097.316	3291			

a. Dependent Variable: lnHospRate

b. Predictors: (Constant), All built 1979 or earlier, Hheat_Elec, Hheat_Kero, Lak_Plumb, Hheat_uTgs, Hheat_LPgs, Edu_25Ndip, Rac_Other, Rac_Asian, Rac_black, Lak_Kitchn, medHH_Inc, Rac_white

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