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16. Abstract

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Asthma is one of the most prevalent chronic conditions in the United States and is particularly sensitive to environmental changes in urban areas. While it is known that traffic congestion contributes to increased vehicle emissions and poorer air quality, its direct association with asthma incidence has not been thoroughly explored. This study aimed to address this void by analyzing 148 city-level observations from 2016 to 2020 in Texas, using data from the Texas A&M Transportation Institute and Definitive Healthcare. We investigated the association between traffic congestion, measured by the travel time index, and annual city-level asthma hospital discharges, while adjusting for refinery productivity, minority groups, and education levels through multivariate regression. Our findings revealed a significant positive correlation between the travel time index and asthma visits, indicating that higher traffic congestion is associated with increased hospital visits for asthma. This finding remains consistent across different models, regardless of whether control variables are included. For the control variables, we found that higher refinery productivity was linked to elevated risks of asthma-related hospitalizations, aligning with previous research findings. Although correlations with Black or African American and Hispanic or Latino populations, as well as those with less than a high school education, were not statistically significant, a positive trend was observed. These results emphasize the impact of traffic congestion on asthma prevalence and the necessity for targeted public health interventions and urban planning strategies.

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Traffic Congestion and Asthma-related Hospital Visits: Evidence from Texas

FINAL REPORT

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LIST OF ABBREVIATIONS

Abbreviation	Description
City FE	city fixed effects
CO	carbon monoxide
CO_2	carbon dioxide
FlOPs	plasma fluorescent oxidation products levels
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
O_3	ozone
$PM_{0.5}$	particulate matter, with a diameter of 0.5 micrometers or less
$PM_{2.5}$	particulate matter, with a diameter of 2.5 micrometers or less
PM_{10}	particulate matter, with a diameter of 10 micrometers or less
SES	socioeconomic status
SO_2	sulfur dioxide
TRAP	traffic-related air pollution
VOCs	volatile organic compounds
Year FE	year fixed effects

ABSTRACT

Asthma is one of the most prevalent chronic conditions in the United States, particularly sensitive to environmental changes in urban areas. While traffic congestion is known to contribute to increased vehicle emissions and poorer air quality, its direct association with asthma incidence remains underexplored. This study aimed to address this void by analyzing 148 city-level observations from 2016 to 2020 in Texas, utilizing data from the Texas A&M Transportation Institute and Definitive Healthcare. This study investigated the association between traffic congestion, measured by the travel time index, and annual city-level asthma hospital discharges, while adjusting for refinery productivity, minority groups, and education levels through multivariate regression. The findings revealed a significant positive correlation between the travel time index and asthma visits, indicating that higher traffic congestion is associated with increased hospital visits for asthma. Additionally, higher refinery productivity was linked to elevated risks of asthma-related hospitalizations. Although correlations with Black or African American and Hispanic or Latino populations, as well as those with less than a high school education, were not statistically significant, a positive trend was observed. These results emphasize the impact of traffic congestion and industrial activities on asthma prevalence and the need for targeted public health interventions and urban planning strategies.

CHAPTER 1: Introduction

Asthma is a significant global health problem, affecting approximately 262 million people and causing 455,000 deaths in 2019 worldwide (World Health Organization, 2023). In the United States, it is one of the most prevalent and costly chronic conditions, and it is particularly susceptible to environmental changes in urban neighborhoods (Ram et al., 2015). In 2021, approximately 4.68 million children and 20.29 million adults had asthma in the United States (Centers for Disease Control and Prevention, 2023). Although asthma is incurable, avoiding known triggers can effectively control and prevent asthma attacks.

It is well known that traffic congestion increases vehicle emissions, a key cause of air pollution, exacerbating asthma and impairing respiratory health, especially near high-traffic areas (Afrin &Yodo, 2020; Kumar et al., 2023; Zhang & Batterman, 2013). Traffic congestion increases emissions of nitrogen oxides (NO_x), particulate matter (PM_{10} and $PM_{2.5}$), carbon monoxide (CO), volatile organic compounds (VOCs), sulfur dioxide (SO_2), and carbon dioxide (CO_2) due to inefficient fuel combustion from slow-moving and idling vehicles. These emissions degrade air quality, leading to the formation of smog and particulate pollution that exacerbates respiratory conditions such as asthma and contributes to cardiovascular diseases. As a result, congested areas, especially in urban environments, experience significant air quality degradation, which severely impacts public health.

Industrial activities also contribute to ambient air pollution, impacting environmental and health issues. Industrial activities contribute significantly to air pollution by emitting harmful pollutants such as PM_{10} and $PM_{2.5}$, SO_2, NO_x, and VOCs. These emissions degrade environmental quality, leading to smog, acid rain, and ecological damage, while severely impacting human health. For example, studies have shown that people living near industrial zones, such as petroleum refineries, exhibit increased rates of asthma, reduced lung function, and heightened respiratory symptoms (Deger et al., 2012; Orru et al., 2018; Puci et al., 2023; Remy et al., 2019; Smargiassi et al., 2009; Wichmann et al., 2009). This evidence highlights the urgent need for stringent regulations to control industrial emissions, protect the environment, and reduce the risk of developing asthma and other public health issues.

Vulnerable populations, including minority groups and individuals from lower socioeconomic backgrounds, consistently confront a greater burden of serious health problems. This is particularly evident in managing chronic conditions such as asthma and eczema. Studies show that these communities are at an increased risk for such conditions due to factors like poor air quality, limited access to healthcare, and inadequate educational resources (Bukstein et al., 2022; Litonjua et al., 1999). Furthermore, these communities face significant challenges, such as higher rates of emergency department visits and hospitalizations, compared to the general population (Bukstein et al., 2022). This intersection of environmental and socioeconomic factors not only amplifies health disparities but also places vulnerable populations at a heightened risk for more serious health problems.

Existing research on the direct association between traffic congestion and asthma is lacking, with few studies comprehensively addressing both environmental and social factors. While previous studies have primarily focused on the effects of traffic-related air pollution on asthma prevalence, the specific impact of traffic congestion, as a distinct source of air pollution, remains underexplored. Notably, only a few studies have conducted a comprehensive analysis that includes both environmental and social determinants of asthma occurrence (Li et al., 2023). This research aims to bridge these gaps by directly exploring the relationship between traffic congestion and asthma, taking into account additional environmental and social factors.

The objective of this research is to comprehensively explore how traffic congestion, alongside other factors, influences asthma prevalence. This study conducted a series of multivariate regression analyses to examine the relationship between traffic congestion, represented by the travel time index, and annual city-level asthma hospital discharges in Texas. Additionally, this study adjusted for other environmental and social factors in the analysis, including refinery productivity, specific minority groups, and education levels.

The report is organized as follows: Chapter 2 provides a review of previous research on asthma-related studies. This includes a discussion of factors associated with asthma risk, such as traffic-related factors, industry-related factors, and social determinants, along with a summary of the findings. Chapter 3 describes the data sources and analysis methods. Chapter 4 presents the results from visual and statistical analyses. Chapter 5 provides a discussion and conclusion.

CHAPTER 2: Literature Review

Existing research has highlighted various risk factors linked to the incidence and prevalence of asthma. This section of the study will review the association of asthma risks with different environmental and social determinants. Specifically, it will focus on traffic-related pollutants and other factors, industrial activities, and broader social determinants affecting asthma. Additionally, this section will synthesize findings from prior studies, providing a comprehensive review of each identified risk factor and their impacts on asthma.

2.1 Traffic-related Air Pollution and Asthma

The relationship between traffic-related air pollution (TRAP) and asthma is well-documented across various studies, emphasizing how exposure to pollutants exacerbates respiratory conditions. This literature review examines findings that link TRAP with an increased risk of asthma development and severity (Table 1).

Zheng et al. (2015) and Hua et al. (2023) focused on the critical periods of early life and short-term exposure to air pollution, especially from traffic sources. Their research indicated a direct correlation between exposure to TRAP during these formative and immediate times and an increased risk of developing asthma, alongside a higher frequency of asthma-related emergency room visits and hospitalizations. These findings highlight the profound impact that early and acute exposure to traffic pollution has on respiratory health.

Table 1. Summary of studies on traffic-related air pollution and asthma.

Study	**Traffic-related air pollution**	**Key Findings**
Zheng et al. (2015)	O_3, CO, NO_2, SO_2, PM_{10} and $PM_{2.5}$	All studied pollutants significantly increased risks of asthma-related emergency room visits and hospitalizations.
Havet et al. (2019)	NO_2, NO_x, PM_{10}, $PM_{2.5}$, and O_3	Increased plasma fluorescent oxidation products levels (FlOPs), affected by PM_{10} and O_3, correlated with higher asthma risk.
Tiotiu et al. (2020), An et al. (2021), Pfeffer et al. (2021)	O_3, NO_2, CO, SO_2, $PM_{2.5}$, PM_{10}, and VOCs	Traffic-related air pollution significantly impacts respiratory distress and asthma across all ages.
Hua et al. (2023)	$PM_{2.5}$, PM_{10}, NO_2, and SO_2	Significant associations found with NO_2 and SO_2 during pregnancy; $PM_{2.5}$ linked to asthma in later trimesters.
Syed et al. (2023)	$PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, VOCs, and O_3	Traffic-related air pollution is linked to various respiratory disorders, such as asthma and chronic obstructive pulmonary disease (COPD).

Expanding on the types of pollutants, Havet et al. (2019) delved into the role of oxidative stress in asthma among adults, linking it to long-term exposure to nitrogen dioxide (NO_2), nitrogen oxides (NO_x), particulate matter (PM_{10} and $PM_{2.5}$), and ozone (O_3). Their study suggested that PM_{10} and O_3 contribute to persistent asthma through biological mechanisms driven by oxidative stress, providing a deeper understanding of how TRAP influences chronic respiratory conditions.

Tiotiu et al. (2020), An et al. (2021), and Pfeffer et al. (2021) further explored the specifics of how different pollutants exacerbate asthma. An et al. (2021) and Pfeffer et al. (2021) examined the role of particulate matter, while Tiotiu et al. (2020) focused on the broader spectrum of TRAP, including volatile organic compounds (VOCs) and their direct impact on increasing asthma symptoms and episodes. These studies collectively demonstrate that the particulate and gaseous components of TRAP are significant contributors to respiratory distress, impacting both the development and exacerbation of asthma in children and adults.

Syed et al. (2023) discussed the comprehensive effects of TRAP, emphasizing the broad public health implications and the need for targeted interventions. Their review integrates the impacts of air pollution on airway diseases with a focus on the synergistic effects of climate change and increased allergens due to environmental pollution.

This body of research underscores the critical need for targeted policy interventions aimed at reducing exposure to traffic-related air pollutants. By understanding the varied and significant impacts of TRAP, especially in densely populated urban areas, public health strategies can be better designed to mitigate these risks and protect vulnerable populations, particularly children and those with pre-existing conditions.

Despite extensive research into the harmful effects of TRAP on respiratory health, the direct connection between traffic congestion—as a concentrated source of air pollution—and asthma remains underexplored. This gap points to the need for further studies that would specifically isolate the impacts of high-density traffic conditions on asthma prevalence and severity.

2.2 Influence of Other Traffic-related Factors

In addition to traffic-related air pollution, several studies have established a positive correlation between various other traffic-related elements and the prevalence of asthma. For instance, traffic volume, as quantified through simple traffic counts, was found to be directly correlated with the incidence of asthma symptoms among urban populations, demonstrating that higher traffic volume may contribute to increased asthma rates (Cakmak et al., 2012). Similarly, Dales et al. (2009) explored the role of road density, finding a strong association between higher road densities near residential areas and elevated asthma symptoms among children, suggesting that closer residential proximity to numerous roads can exacerbate respiratory conditions.

Adding to this body of knowledge, Bowatte et al. (2018) and Pereira et al. (2009) investigated the impact of residential proximity to roadways. Their research concluded that individuals living nearer to major roadways experience higher rates of asthma, attributed to increased exposure to traffic emissions and particulate matter. These findings indicate that the physical closeness of homes to traffic not only elevates direct exposure to harmful pollutants but also significantly influences respiratory health.

However, despite these insights, the specific impact of traffic congestion on asthma exacerbation tends to be underestimated. Pereira et al. (2009) emphasized this point, suggesting that the congestion component of traffic-related exposure—often manifested in prolonged vehicle idling and increased emission concentrations during peak traffic hours—plays a crucial role in asthma exacerbation yet is frequently overlooked in research and urban health policies.

2.3 Industrial Activity and Asthma

The relationship between industrial emissions and the prevalence and exacerbation of asthma is notably significant. This review consolidates findings from various studies, revealing the pervasive impact of industrial pollutants on people's respiratory health (Table 2).

Table 2. Summary of studies on industrial activities and asthma.

Study	Factor(s) Studied	Key Findings
Wichmann et al. (2008)	PM_{10}, $PM_{2.5}$, $PM_{0.5}$, VOCs from petrochemicals	Children near a petrochemical plant had increased asthma symptoms, exacerbations, and reduced lung function.
Smargiassi et al. (2009)	SO_2 levels near refinery stacks	Short-term increased SO_2 exposures correlated with more asthma episodes in children nearby.
Deger et al. (2012)	SO_2 from petroleum refineries	Proximity to refinery SO_2 emissions linked to higher asthma prevalence and poorer asthma control in children.
Orru et al. (2018)	Benzene, phenol, and $PM_{2.5}$ from oil shale sectors	Higher levels of $PM_{2.5}$ associated with more respiratory symptoms like chest tightness and asthma attacks.
Puci et al. (2023)	Living near a refinery, age, sex, and smoking status	Higher asthma and COPD prevalence in residents near refineries, with smokers at greater risk for these conditions.

Studies by Deger et al. (2012) and Wichmann et al. (2008) present compelling evidence that proximity to industrial zones, such as petrochemical refineries, substantially increases asthma rates among children. These studies found that not only is asthma more prevalent, but the symptoms associated with respiratory conditions are more severe compared to those in children living in cleaner environments.

The work of Smargiassi et al. (2009) alongside Deger et al. (2012) highlights that both short-term and chronic exposures to pollutants like sulfur dioxide (SO_2) significantly deteriorate respiratory health. These pollutants often lead to an immediate increase in respiratory symptoms and hospital visits due to asthma exacerbations, underscoring the acute impacts of industrial pollutants.

The study by Orru et al. (2018) indicates that long-term exposure to industrial pollutants, such as $PM_{2.5}$ can lead to persistent respiratory conditions, suggesting that the effects of exposure extend beyond immediate health crises to potentially lifelong respiratory problems. Research by Puci et al. (2023) further investigates how socioeconomic factors intersect with environmental exposure. Smokers living near a refinery had a higher risk of developing both asthma and chronic obstructive pulmonary disease (COPD).

The evidence from these studies strongly advocates for enhanced regulatory oversight and public health strategies focused on reducing the exposure of children and adults to harmful industrial emissions. Effective intervention can mitigate the risks and improve health outcomes for people living in proximity to industrial areas.

2.4 Studies on Social Determinants

Research into the relationship between social factors and asthma prevalence reveals significant disparities, with a variety of social determinants playing a crucial role in asthma outcomes (Table 3).

Table 3. Summary of studies on social determinants and asthma.

Study	Key Findings
Litonjua et al. (1999)	Increased asthma risk associated with lower income, education, and high poverty areas; Blacks and Hispanics more affected.
Grineski et al. (2014)	Poor and minority children with limited care access had increased odds of seeking urgent and emergency care.
Keet et al. (2014)	Black, Puerto Rican, and lower-income children had higher asthma rates; poverty impacts varied by ethnicity.
Bukstein et al. (2022)	Health literacy issues, fewer asthma plans, and more emergency care visits noted among Black, Hispanic, and low-income participants.
Tyris et al. (2022)	Lower educational attainment correlated with higher asthma-related emergency visits.
Li et al. (2023)	Asthma exacerbations associated with air pollution, drilling, old housing; inversely with green spaces.

Litonjua et al. (1999) investigated the effects of race, socioeconomic status (SES), and residence on asthma prevalence, finding that minority groups such as Black and Hispanic individuals faced significantly higher asthma rates than White counterparts. These differences were primarily attributed to low SES and environmental conditions, with low income, limited education, and living in high-poverty neighborhoods being consistent risk factors across both adult and child cohorts.

Bukstein et al. (2022) highlighted the significant burden of asthma on marginalized populations, particularly those facing economic hardships or belonging to racial and ethnic minorities. Individuals from Black and Hispanic backgrounds and those with low incomes were more likely to require emergency department visits for asthma and to face health literacy barriers that impede understanding medical documents and treatment plans. Moreover, these populations often have reduced access to healthcare resources due to inadequate insurance coverage and transportation issues.

Research by Grineski et al. (2014) examined how social disparities are associated with asthma. They found that children from low-income families, those with limited access to care, those with a Spanish-speaking caretaker, or those with a foreign-born caretaker, were more likely to have an increased risk of asthma. The results highlight a heightened vulnerability that can exacerbate respiratory health issues.

Keet et al. (2014) underscored how race/ethnicity and socioeconomic challenges contribute to asthma disparities, noting that minority children facing household poverty are at a higher risk of asthma. Education level also plays a pivotal role in shaping asthma outcomes, where lower parental education often leads to insufficient disease management knowledge (Tyris et al., 2022). Tyris et al. (2022) emphasized the need for culturally sensitive educational strategies to address literacy barriers and develop shared decision-making practices for managing asthma. However, it is noteworthy that only a limited number of these studies have undertaken a comprehensive analysis of both environmental and social factors in relation to asthma occurrence (Li et al., 2023).

The collected research consistently shows that social determinants such as socioeconomic status, race, and access to healthcare are influential in shaping asthma disparities. Addressing these disparities requires comprehensive strategies involving environmental regulation, healthcare system improvements, and community education. This will enable the implementation of tailored interventions to mitigate the effects of social factors on asthma prevalence and ensure equitable health outcomes.

CHAPTER 3: Materials and Methods

3.1 Data Source

This study collected city-level data on asthma-related hospital visits in Texas from Definitive Healthcare and traffic congestion data from Texas A&M Transportation Institute. Asthma visits is represented by the annual asthma discharges, measured in thousands, from cities in Texas. Traffic congestion is represented by the travel time index, which is the ratio of travel time in the peak period to the travel time under free-flow conditions. In total, the dataset comprises 148 city-level observations from 2016 to 2020. Additionally, this research gathered refinery productivity data, measured in barrels per day, from the Arnold & Itkin website (2024) as well as demographic and educational variables from the U.S. Census American Community Survey. These variables include the percentage of Black or African American, the percentage of Hispanic or Latino, and the percentage of the population with less than a high school education (Age ≥ 18). Table 4 shows the descriptive statistics of the variables.

Table 4. Descriptive statistics of variables.

Variables	Minimum value	Maximum value	Average value	Medium value	Standard deviation
Asthma visits (in thousands)	0.302	51.194	8.733	3.887	11.179
Travel time index	1.040	1.350	1.131	1.100	0.075
Refinery	0	1199	97.010	0	264.854
Percentage of Black or African American	0.382	48.501	13.650	8.467	11.844
Percentage of Hispanic or Latino	14.387	95.549	43.942	35.051	23.204
Percentage of no high school diploma	7.010	33.539	16.957	15.771	5.783

3.2 Visual Analysis

In this research, thematic maps were utilized to examine the interaction between asthma visits and the travel time index. This study initially mapped the spatial distribution of both asthma visits and the travel time index to visually investigate the relationship between asthma visits and traffic congestion. Subsequently, the top four cities were selected to better visualize the trends of asthma visits and the travel time index over time.

3.3 Regression Model

This research conducted a series of multivariate regression analyses in Stata 17.0, significant at the 0.01, 0.05, and 0.1 levels, to examine the association between traffic congestion and asthma visits in Texas, adjusting for factors including refinery productivity, the percentage of Black or African American, the percentage of Hispanic or Latino, and the percentage of the population with less than a high school education. The equation of the regression model is represented as below:

$$Asthma_{visits} = \beta_0 + \beta_1 Traffic_{congestion} + \sum Controls + City\ FE + Year\ FE + \varepsilon \qquad (1)$$

In this model, $Asthma_{visits}$ represents the number of asthma-related hospital visits in Texas, while $Traffic_{congestion}$ quantifies traffic congestion using the travel time index. The term β_0 denotes the intercept, and β_1 is the coefficient corresponding to traffic congestion. $\sum Controls$ encompasses the sum of additional variables, such as refinery productivity, the percentage of Black or African American, the percentage of Hispanic or Latino, and the percentage of the population with less than a high school education. $City\ FE$ and $Year\ FE$ refer to city-specific and year-specific fixed effects, respectively, to control for temporal and city variations. ε represents the error term, accounting for any residual variation in asthma visits not explained by the model.

CHAPTER 4: Results

4.1 Results of the Visual Analysis

The spatial distribution of the travel time index and asthma visits from 2016 to 2020 is shown in Figures 1-5, revealing that cities with higher values of the travel time index also tended to have a greater number of asthma visits. In 2020, there was a notable decline in both the travel time index and asthma visits across the board, particularly evident in the top four cities: Austin, Dallas, Houston, and San Antonio. These cities had previously displayed relatively stable numbers of the travel time index (Figure 6) and asthma visits (Figure 7) from 2016 to 2019. In 2020, however, both the travel time index and asthma visits significantly decreased.

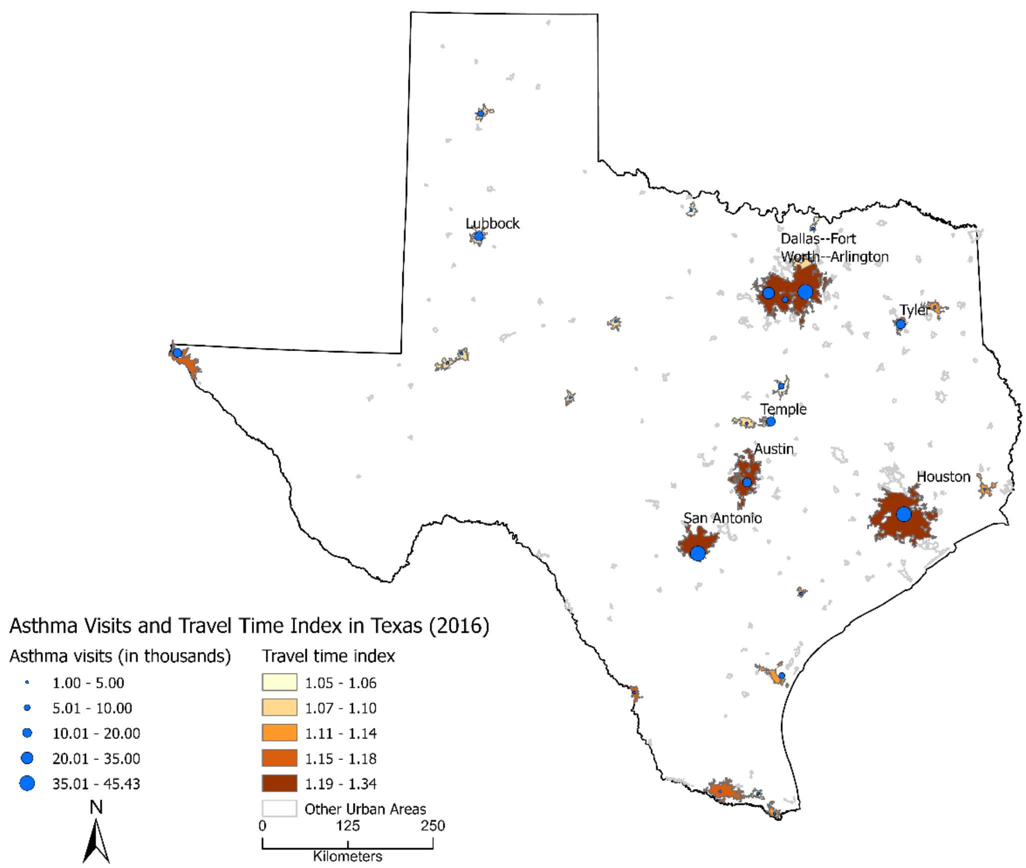

Figure 1. Asthma visits and travel time index in Texas in 2016.

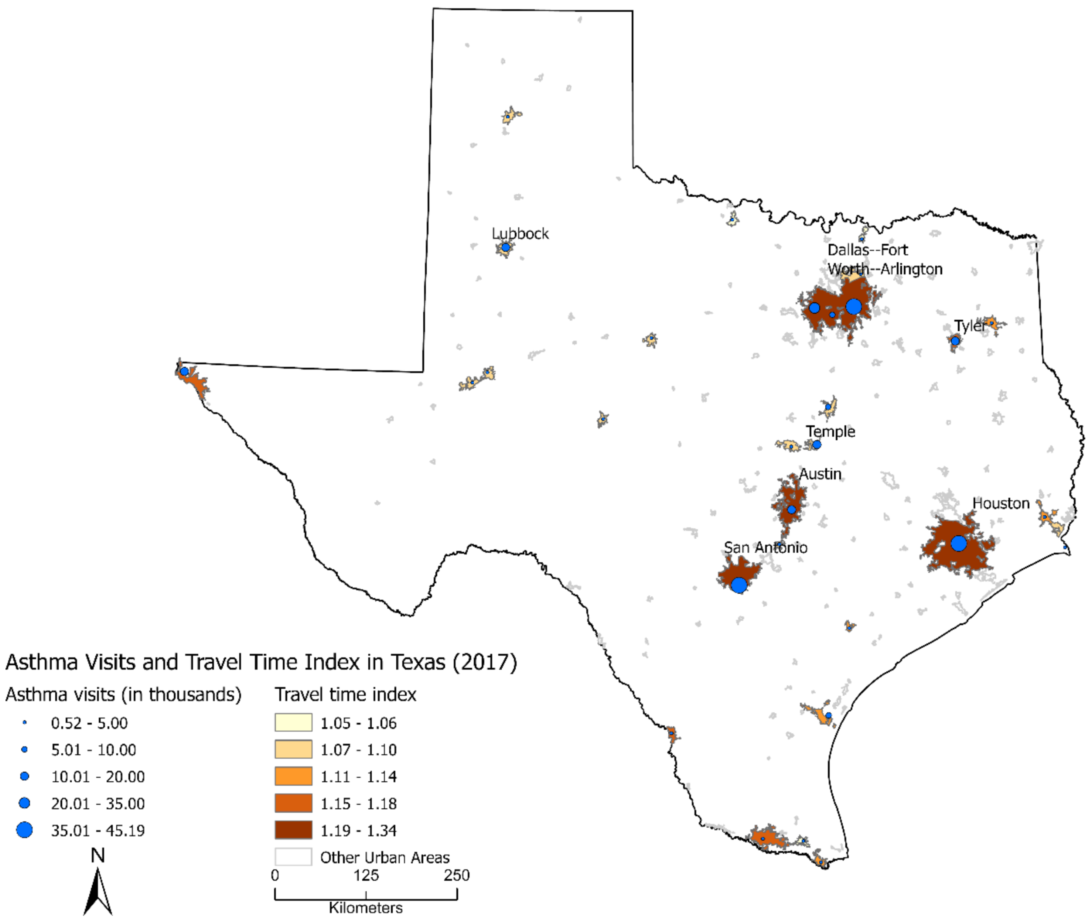

Figure 2. Asthma visits and travel time index in Texas in 2017.

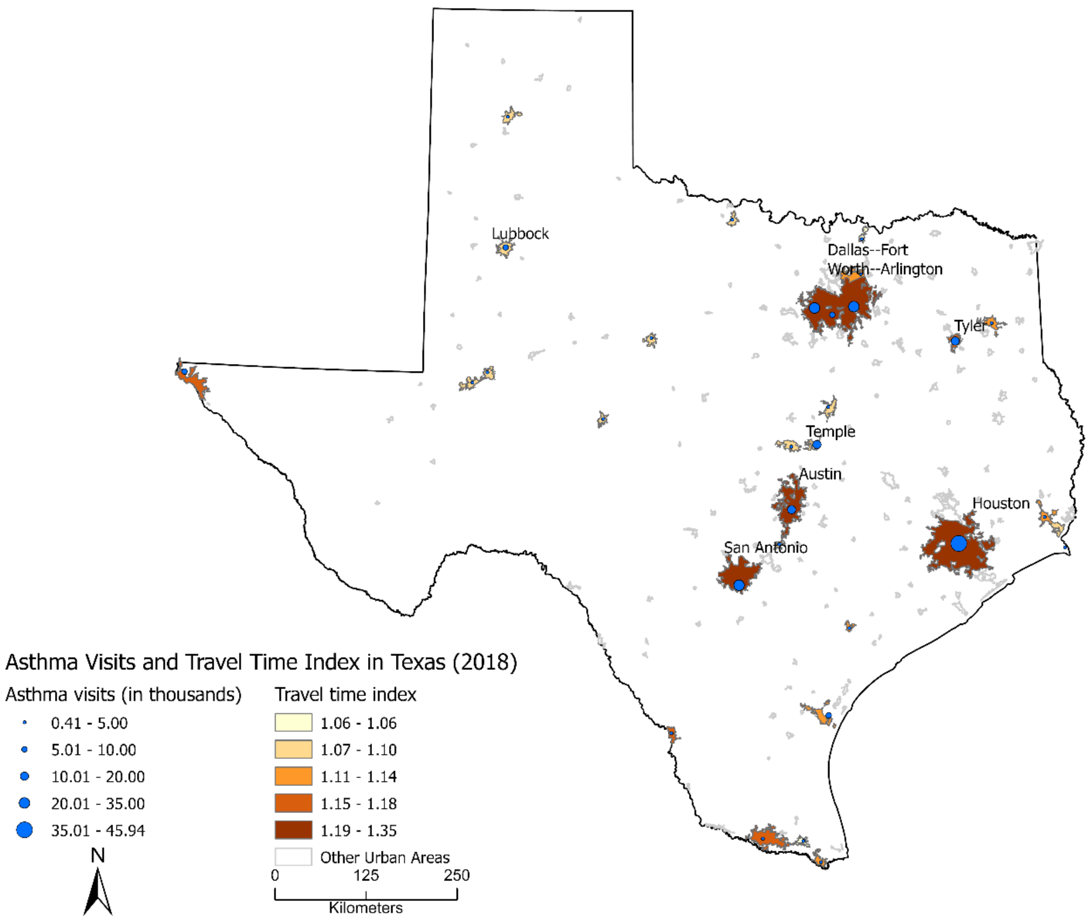

Figure 3. Asthma visits and travel time index in Texas in 2018.

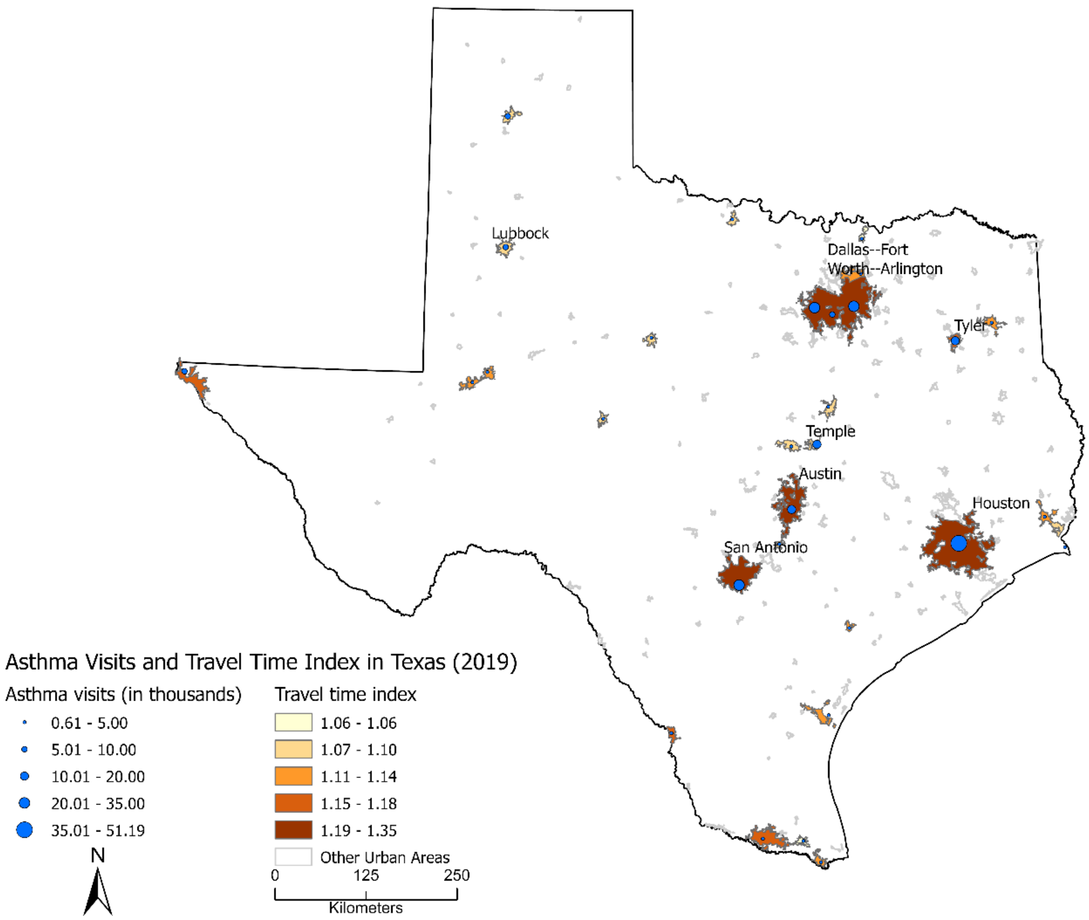

Figure 4. Asthma visits and travel time index in Texas in 2019.

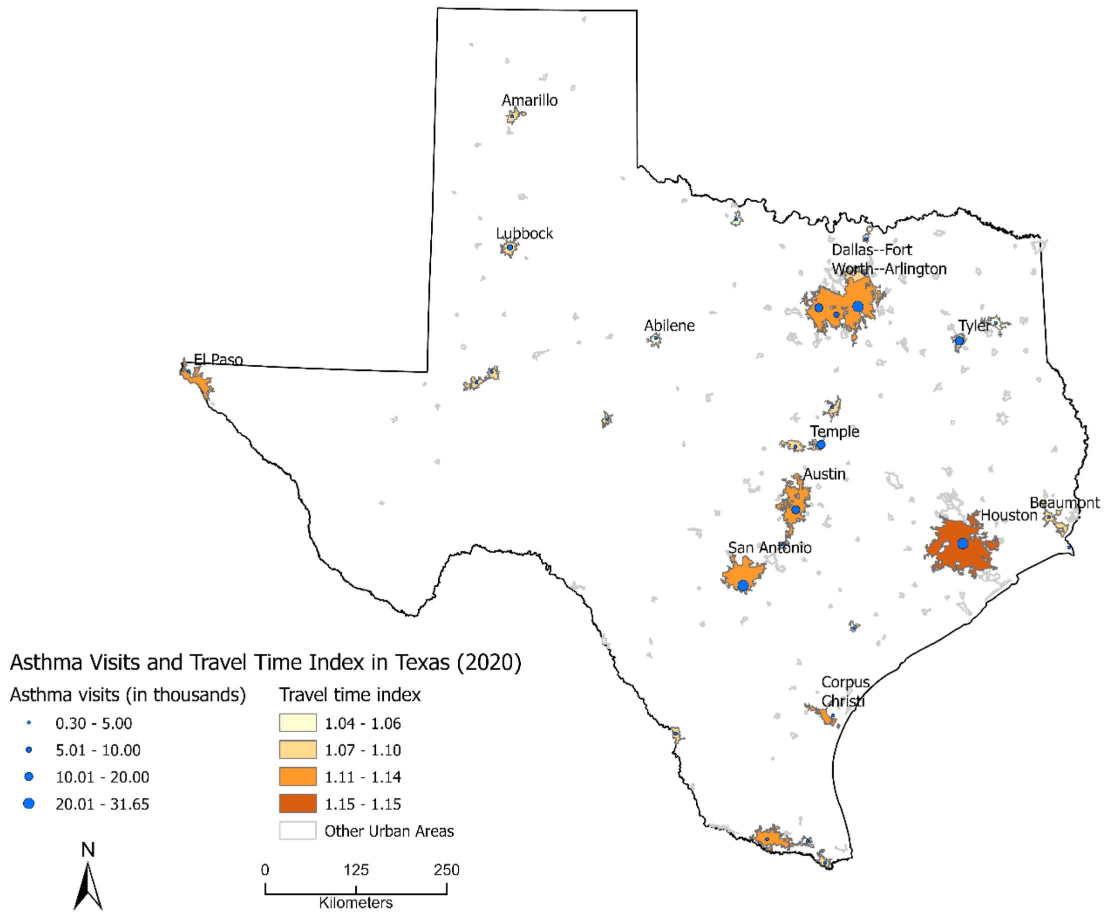

Figure 5. Asthma visits and travel time index in Texas in 2020.

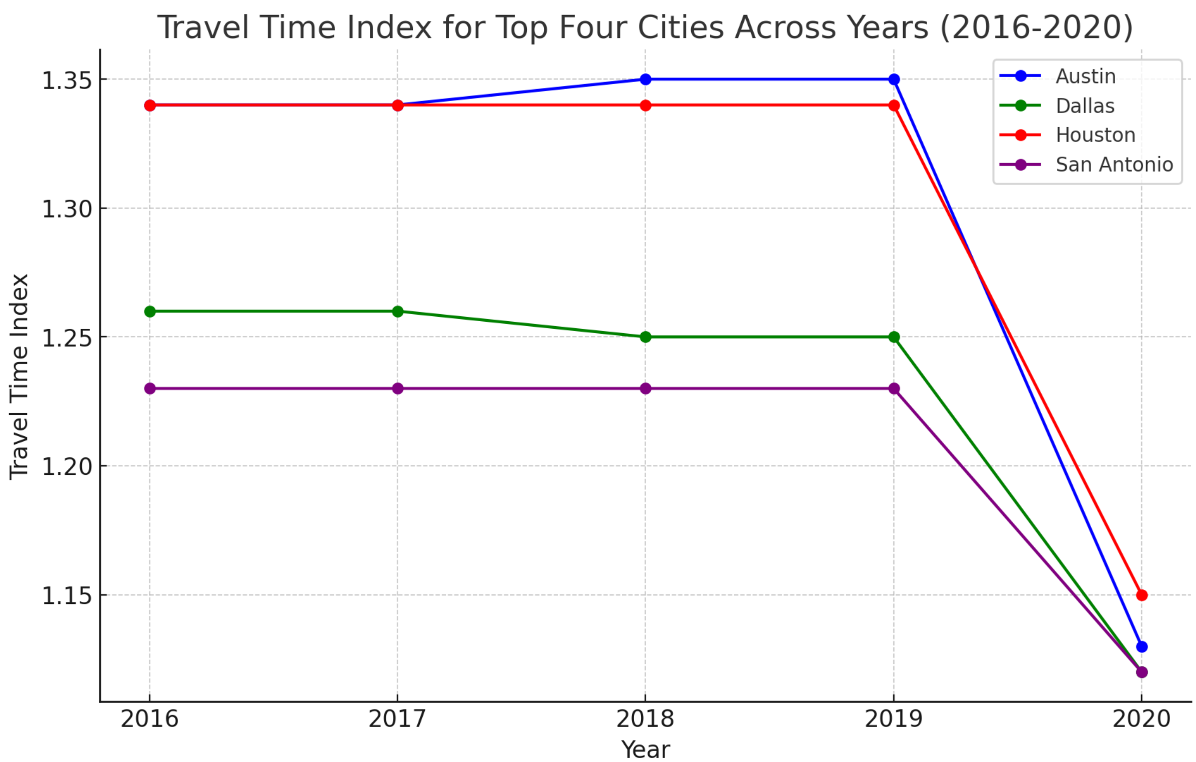

Figure 6. Top four Texas cities: Travel time index from 2016 to 2020.

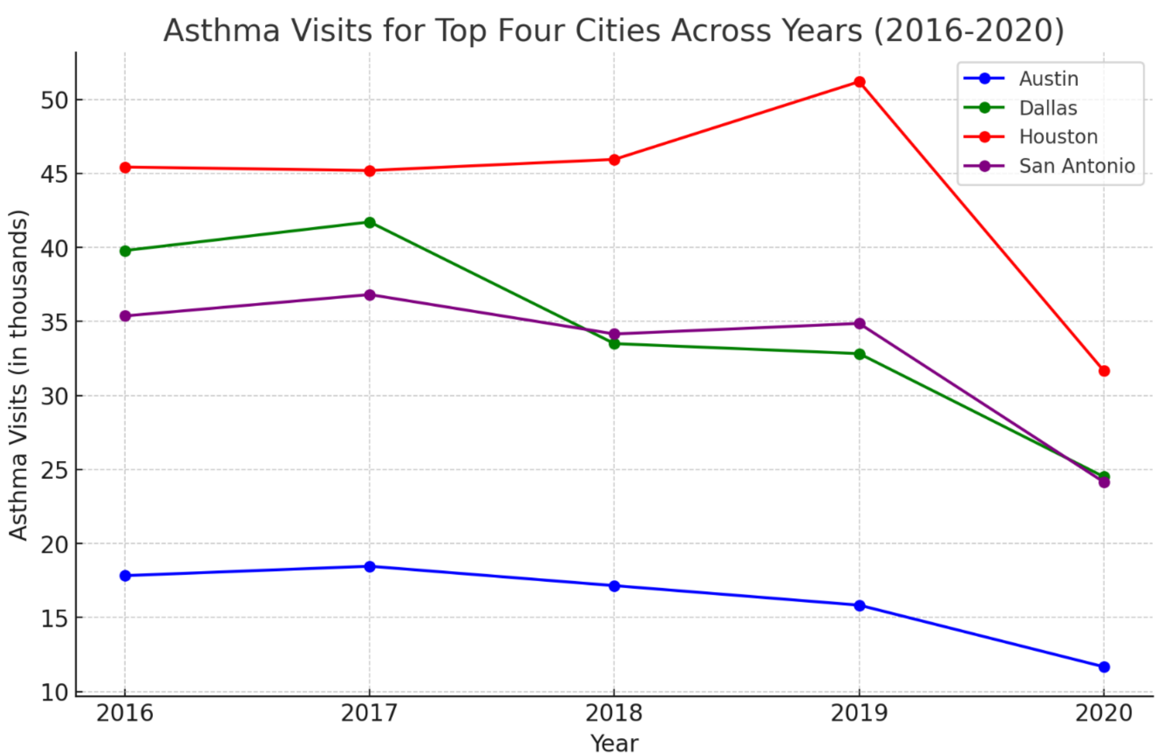

Figure 7. Top four Texas cities: Asthma visits from 2016 to 2020.

4.2 Results of the Regression Analysis

Table 5 shows the results of different models, controlling for environmental and sociodemographic variables. In the first model, which only included the travel time index, a significant positive relationship was observed between the travel time index and asthma-related hospital visits. This indicated that higher traffic congestion is associated with an increase in hospital visits for asthma. After adjusting for the refinery productivity factor in the second model, the travel time index still maintained a significant positive association with asthma visits. Furthermore, refinery productivity was also significantly positively associated with asthma visits, suggesting that higher refinery productivity elevates the risk of asthma-related hospitalizations.

Table 5. Association between asthma visits, travel time index, and other factors.

Variables	**Asthma visits Model 1**	**Asthma visits Model 2**	**Asthma visits Model 3**	**Asthma visits Model 4**
Travel time index	**45.5049*****	**45.5049*****	**44.9717*****	**44.8881*****
(p-value)	(0.001)	(0.001)	(0.001)	(0.001)
Refinery		**1.1640*****	**1.0552****	**1.1202****
(p-value)		(0.000)	(0.024)	(0.013)
Percentage of Black or African American			0.1142	0.0984
(p-value)			(0.666)	(0.710)
Percentage of Hispanic or Latino			0.0705	0.0141
(p-value)			(0.783)	(0.955)
Percentage of no high school diploma				0.2050
(p-value)				(0.600)
Constant	-44.3392***	-44.3392***	-46.7887***	-48.0179***
(p-value)	(0.003)	(0.003)	(0.004)	(0.005)
Observations	148	148	148	148
Adjusted R-square	0.973	0.973	0.973	0.973
City FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

City FE, city fixed effects; Year FE, year fixed effects.
* An asterisk next to a number indicates a statistically significant p-value: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The specific p-values of the regression coefficients are given in parentheses.

The third model included the travel time index, refinery productivity, and demographic data on minority groups, including percentages of Black or African American and Hispanic or Latino populations. The results showed that the associations of the travel time index and refinery productivity with asthma visits remained significant and positive. While there was a positive association between asthma visits and the percentages of Black or African American and Hispanic or Latino populations, this association was not statistically significant.

In the fourth model, which included the percentage of the population with less than a high school education, the results remained consistent. The travel time index and refinery productivity continued to exhibit a significant positive association with asthma visits. On the other hand, the percentages of the Black or African American and Hispanic or Latino populations, as well as the percentage of the population with less than a high school education, exhibited a positive association with asthma visits, although these relationships were not statistically significant.

The economic magnitude of the result shows that when the travel time index increases (or decreases) by one unit, the average hospital asthma discharge from a city in Texas will increase (or decrease) by 45 thousand. Because the range of the travel time index is only 0.3, it is unreasonable that the travel time index increases by one unit. Realistically, when the travel time index increases (or decreases) by ten (10) percent, the average hospital asthma discharge from a city in Texas will increase (or decrease) 4.5 thousand.

CHAPTER 5: Discussion and Conclusion

This study identified the travel time index and refinery productivity as significant risk factors linked to asthma visits, suggesting that increased traffic congestion and higher refinery productivity are associated with a higher risk of asthma-related hospitalizations. These findings highlight the significant influence of both traffic congestion and industrial activities on asthma prevalence, emphasizing the need for targeted public health interventions and strategic urban planning. Community-level strategies, such as designing “smart” cities with increased green spaces distanced from major traffic routes and industrial zones, promoting public transit, supporting active transportation modes like walking and cycling, and investing in infrastructure for alternative fuel vehicles, can help mitigate the environmental effects of the transportation system and industrial activity. These activities reduce emissions, enhance air quality, and have the potential to decrease asthma and other respiratory diseases, or lower the risk of these conditions.

5.1 Decreased Traffic Congestion and Asthma Visits in 2020

The COVID-19 pandemic and associated restrictions, such as stay-at-home orders, work-from-home policies, and school closures, led to a significant decrease in vehicle trips and consequently reduced traffic volumes and congestion across various states in the United States (Fisher & LaMondia, 2023; Parr et al., 2020; Shearston et al., 2021). Specifically, traffic congestion in New York city dropped sharply immediately after the pandemic was declared in March 2020 (Shearston et al., 2021). In Florida, the statewide traffic volume for 2020 decreased by 47.5% compared to 2019 (Parr et al., 2020). Similarly, in Texas, urban counties experienced a greater reduction in vehicle miles traveled compared to rural counties (Fisher & LaMondia, 2023), contributing to the observed decrease in traffic congestion in 2020 compared to previous years in this project. Additionally, given the association between traffic congestion and asthma visits, the reduction in traffic congestion during the pandemic can also explain the observed decrease in asthma visits during the same period.

5.2 Association Between Traffic Congestion and Asthma

Research has shown that traffic-related air pollution is linked to an increased incidence of asthma (Bowatte et al., 2018; Havet et al., 2019; Jacquemin et al., 2009a, 2009b; Zheng et al., 2015). Specifically, pollutants such as nitrogen dioxide (NO_2) were positively associated with both asthma scores and incidence (Bowatte et al., 2018; Jacquemin et al., 2009a, 2009b). Furthermore, other air pollutants including ozone (O_3), carbon monoxide (CO), sulfur dioxide (SO_2), particulate matter (PM_{10} and $PM_{2.5}$) have been linked to an increased risk of asthma-related emergency room visits and hospitalizations (Havet et al., 2019; Zheng et al., 2015). However, these studies primarily focus on the impacts of traffic-related pollutants on asthma, rather than establishing a direct connection between traffic congestion itself and asthma incidence.

Previous studies have established a connection between efforts to reduce traffic congestion and a subsequent decrease in O_3 and other air pollutants, leading to significantly lower rates of asthma events in both children and adults (Friedman et al., 2001; Li et al., 2011). While these studies did not directly examine the impact of traffic congestion on asthma, their findings lend support to the conclusion in this project that higher traffic congestion is associated with an increased risk of asthma visits. This underlines the importance of interventions aimed at controlling traffic load, such as the implementation of appropriate traffic-restricted zones (Jan et al., 2020), to mitigate both traffic congestion and asthma occurrences.

5.3 Association Between Refinery Productivity and Asthma

Living close to refinery areas and exposure to refinery emissions significantly impacts asthma prevalence and exacerbations. For instance, children living within 10 kilometers of industrial areas exhibited a higher prevalence of asthma, likely due to increased exposure to petrochemical pollutants (Wichmann et al., 2009). Similarly, adults living near refineries, especially in zones with elevated $PM_{2.5}$ levels, report more frequent asthma attacks (Orru et al., 2018). Additionally, emissions from petroleum refineries, including SO_2, were linked to higher rates of active asthma, poor asthma control, and more frequent emergency department visits and hospitalizations related to asthma (Deger et al., 2012; Smargiassi et al., 2009).

A generally higher prevalence of asthma has been observed among populations living near refineries compared to the general population (Puci et al., 2023), with specific incidents like chemical releases from refineries exacerbating the situation (Remy et al., 2019). Similar to previous studies, this project found that higher refinery productivity was associated with increased asthma visits. Although previous studies focus on the effects of living near refineries or refinery emissions, this project differs as it examines how refinery productivity influences asthma-related healthcare visits.

5.4 Disadvantaged Populations and Asthma Incidence

Various studies consistently highlight asthma as a significant health concern among disadvantaged populations, particularly racial and ethnic minorities in urban areas (Corburn et al., 2006). Li et al. (2023) found a notable association between Black adults and asthma exacerbation. Thakur et al. (2017) reported that African American children and low socioeconomic status Mexican American youth faced a higher risk of developing asthma. Similarly, Bukstein et al. (2022) observed that Black and Hispanic individuals were more likely to require emergency department visits or hospitalizations for asthma than the White participants. These findings align with this project's results, which, although not statistically significant, suggest a positive association between asthma visits and Black or African American and Hispanic or Latino populations. This consistency across studies highlights the urgent need to address asthma in these vulnerable groups.

Lower educational attainment, particularly less than a high school education, consistently correlates with asthma exacerbation and increased asthma risk across various studies (Li et al., 2023; Litonjua et al., 1999; Tyris et al., 2022). These studies demonstrate that adults with less than a high school education experience a significant association with asthma exacerbation (Li et al., 2023). Similarly, individuals with less than a high school education, including both parents and children, exhibit an increased risk of asthma (Litonjua et al., 1999). Furthermore, decreased educational attainment positively correlates with elevated rates of pediatric asthma-related emergency department visits and hospitalizations (Tyris et al., 2022). These findings affirm this project's observation that individuals with less than a high school education experience increased asthma visits, although this result is not statistically significant. Together, these results emphasize the impact of education on asthma prevalence and highlight the necessity for targeted interventions in populations with lower educational backgrounds.

5.5 Contribution and Limitation

One notable contribution of this study is its direct examination of the association between traffic congestion and asthma-related hospital visits, which provides empirical evidence that contributes significantly to the existing body of knowledge. Previous studies primarily focused on the effects of traffic-related air pollution on asthma prevalence, and the findings from this study help bridge some gaps by elucidating the direct impacts of traffic congestion on asthma incidence. This knowledge not only highlights the importance of addressing traffic congestion as a public health priority but also informs future research, policy development, and urban planning efforts aimed at mitigating the adverse health effects of transportation-related congestion and air pollution on vulnerable populations. However, a limitation of this study is the absence of demographic details such as age and sex information for the asthma visits, which restricts the generalizability of our findings. Future investigation into different age and sex groups, such as separate child and adult asthma cohorts, may yield varying results regarding the risk factors and provide a more comprehensive insight into the impacts of traffic congestion.

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