THE RELATIONSHIP BETWEEN TRAFFIC-ADJACENT AIR POLLUTION AND HEALTH CHALLENGES IN SAN FRANCISCO BAY AREA

by
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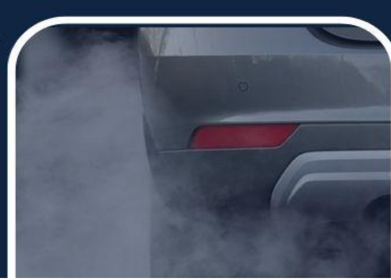

A Master Report Submitted to
the Department of Urban and Regional Planning

San Jose State University

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in San Francisco Bay Area

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Introduction

The significance of this study lies in its analysis of the effects of job growth, particularly in urban areas such as the San Francisco Bay Area. As employment opportunities grow, traffic increases, resulting in increasing levels of pollution. This causal chain illustrates the interconnected nature of economic development, transportation infrastructure, and environmental degradation. It is important to raise awareness among policymakers and urban planners of the numerous consequences of uncontrolled urban growth.

This study investigates the relationship between residential proximity to high-traffic areas and adverse health outcomes, particularly prevalent in the San Francisco Bay Area. Due to its dense network of highways and crowded urban centers, the region provides an ideal research environment for investigating the relationship between traffic-adjacent pollutants and health problems. Research (Liao, Ho-Tang, 2022) has shown that living near highways increases the risk of respiratory ailments, cardiovascular diseases, and developmental disorders. However, it is critical that a comprehensive understanding of this relationship is developed within the context of the Bay Area in order to develop targeted intervention strategies and public health strategies.

In this research, we examine the impact of proximity to highways on public health outcomes in the San Francisco Bay Area. We were able to identify intricate patterns of traffic pollution across the region through the use of principal component analysis (PCA) in SPSS in order to mitigate data redundancy and enhance data accuracy. To identify hotspots of pollution and vulnerability, we use advanced geospatial tools such as ArcGIS Pro to map out the spatial distribution of these pollutants and their health outcomes. According to our findings, areas near highways exhibit elevated concentrations of traffic-adjacent pollutants, which are associated with increased levels of asthma, low birth weight, and respiratory problems for residents. Consequently, there is an urgent need for targeted mitigation measures and urban planning strategies to reduce the health burdens borne by communities disproportionately affected by traffic-adjacent pollution.

Geoprocessing tools such as the "Near" tool enable us to quantify the distance between population centroids and highways, which is an important indicator of how traffic-adjacent pollution affects air quality. It appears that traffic pollution is directly related to adverse health outcomes when looking at health data intersected by highways, particularly around busy corridors like I-880 in the Bay Area. In addition, Principal Component Analysis (PCA) provides further support for the positive relationships between traffic pollution and health outcomes, emphasizing the interconnectedness of environmental factors and community well-being.

Background knowledge

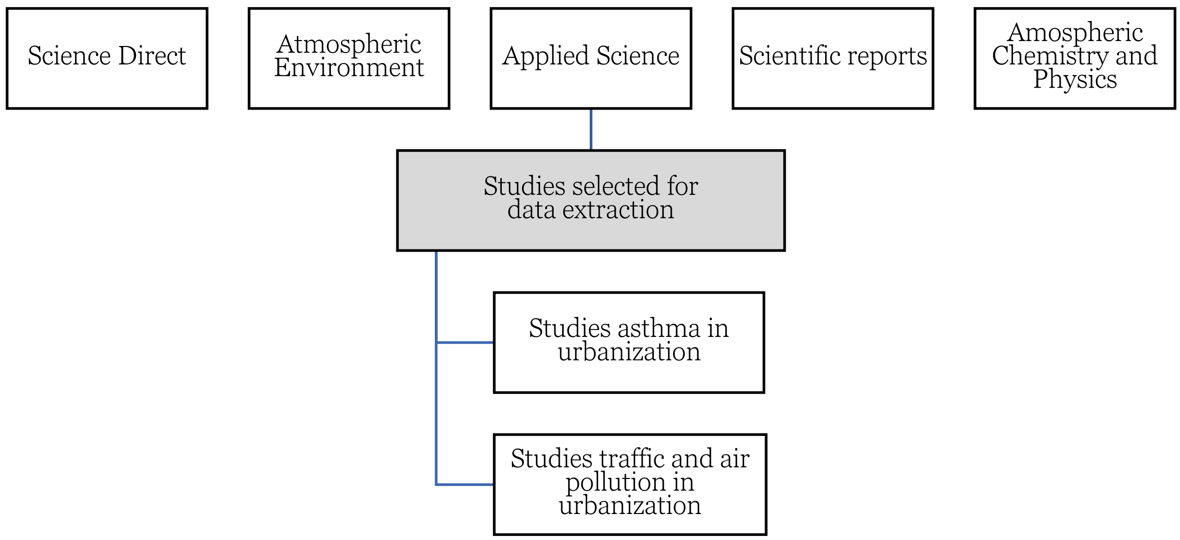
The San Francisco Bay Area is renowned for its cultural diversity and energetic urban hubs. Despite this, the region faces significant challenges concerning air pollution and public health, particularly concerning respiratory ailments, cardiovascular diseases, and developmental disorders.

Traffic-adjacent air pollution is a primary contributor to the San Francisco Bay Area's poor air quality and has been linked to various health outcomes. According to the American Lung Association, the San Francisco-Oakland-Hayward area ranks as the 8th most polluted metropolitan area in the US in terms of ozone pollution, a significant component of traffic-adjacent air pollution (American Lung Association, 2023).

To address the issue of traffic-adjacent air pollution, the Bay Area Air Quality Management District has implemented several policies, including regulations on vehicle emissions and initiatives to promote alternative transportation modes. However, further research is required to comprehend the relationship between traffic-adjacent air pollution and health outcomes in the region and to inform public health interventions and policies aimed at reducing respiratory disease in the area.

Literature Reviews

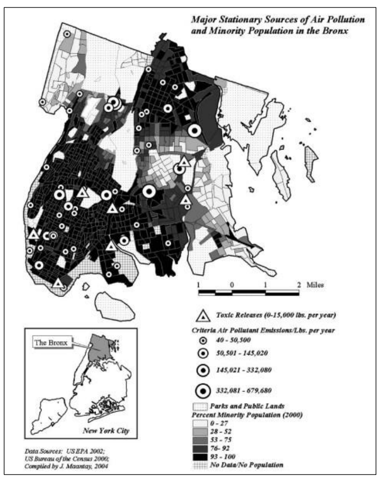
Publication selection process



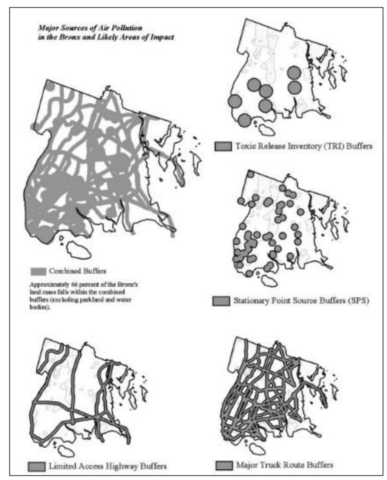
Several reputable article platforms, such as ScienceDirect, Atmospheric Environment, Applied Science, Scientific Reports, and Atmospheric Chemistry and Physics, were utilized for the literature review conducted for this project regarding asthma in urbanization and its relationship to traffic and air pollution. Using findings from these diverse sources, I have been able to develop a comprehensive understanding of the relationship between traffic air pollution and respiratory prevalence. These literature reviews examine in detail the complex interplay between traffic pollution and air quality in exacerbating respiratory conditions such as asthma, which will provide a solid basis for further study and intervention strategies in the future.

Environmental problems and traffic air problems:

Juliana Maantay (2007) explores the use of Geographic Information Systems (GIS) in assessing environmental justice, using a case study of the relationship between asthma and air pollution in the Bronx, New York City. The study highlights several challenges in conducting environmental justice assessments, including issues related to spatial extent and resolution, selection of environmental burdens to analyze, data and methodological limitations, and different approaches to delineating exposure. Through proximity analysis, the study found that individuals living in close proximity to noxious land uses were at a higher risk of hospitalization for asthma, and that these individuals were more likely to be poor and belong to a minority group. This study provides valuable insights into the application of GIS in environmental justice research and underscores the importance of taking into account social and environmental factors when analyzing health outcomes.

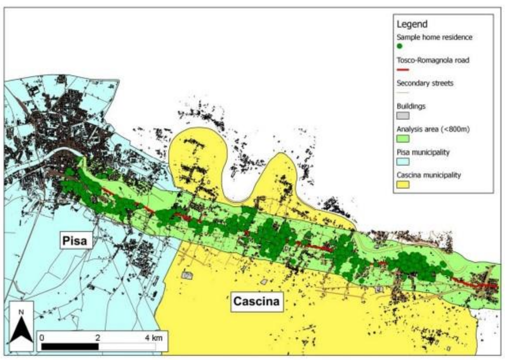


Major stationary sources of air pollution and minority population in the Bronx

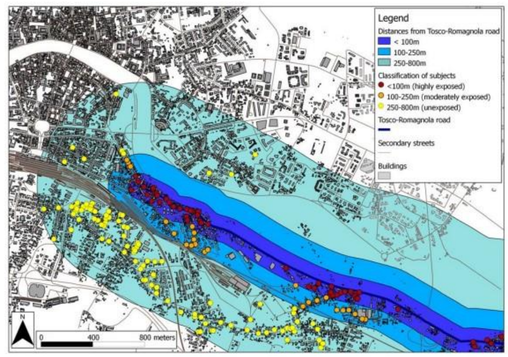


Proximity Buffers

Daniela Nuvolone (2012) examined the impact of distance from a main road on respiratory health status using a Geographical Information System (GIS) approach. The researchers used data collected from an epidemiological survey in the Pisa-Cascina area, central Italy, between 1991-1993. The study included 2,062 subjects, and highly exposed subjects were defined as those living within 100 m of the main road, moderately exposed as those living between 100 and 250 m from the road, and unexposed as those living between 250 and 800 m from the road. The study found that compared to subjects living between 250 m and 800 m from the main road, subjects living within 100 m of the main road had increased risks for respiratory symptoms and diseases, including persistent wheeze, COPD diagnosis, reduced FEV1/FVC ratio, dyspnea, positivity to skin prick test, asthma diagnosis, and attacks of shortness of breath with wheeze. The study highlights the potential effects of traffic-adjacent air pollution on respiratory health status, including lung function impairment, and the added value of GIS in environmental health research.

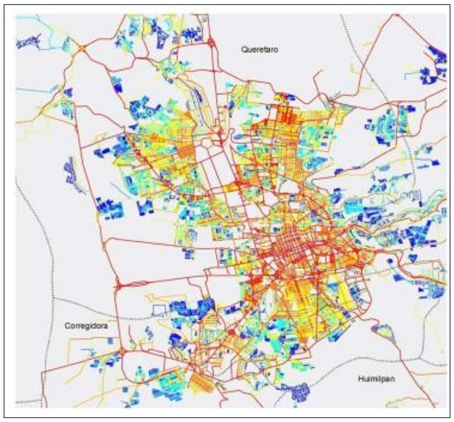


Study area and geocoding of population sample

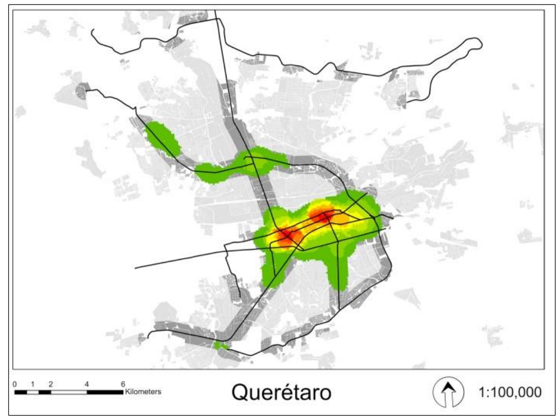


Classification of subjects based on the distance of each home from the main road

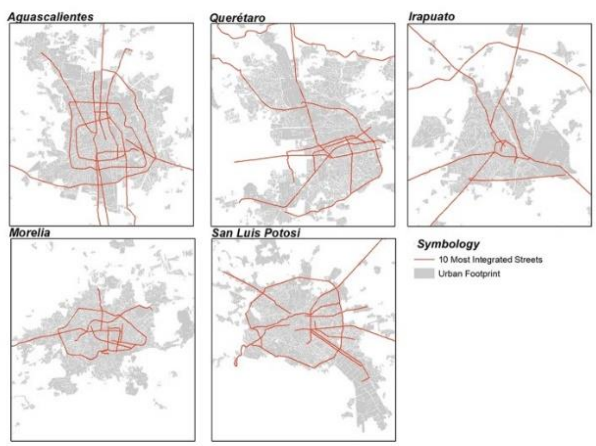
Ruben Garnica-Monroy (2022) investigated the significant impact of traffic on air quality in cities, with proximity to roadways with heavy traffic being linked to a range of health effects, including adverse birth outcomes, dementia, asthma, bronchitis, and lung function deficits. In Mexico, the lack of air quality monitoring in many cities poses a challenge for assessing current exposure levels to Traffic-adjacent Air Pollution (TRAP) and designing effective policies to reduce its impact on the population. The study proposes an approach to estimate the proportion of the population potentially exposed to TRAP using Space Syntax's accessibility index as the urban form variable. The study focuses on the ten most accessible roads of five Mexican cities and estimates the proportion of vulnerable populations with the highest potential exposure to TRAP at a distance of 500 m. The findings suggest a similar proportion of the population continually exposed to TRAP due to proximity to roads with heavy traffic as studies use more complex models. The study concludes by presenting alternatives to reduce the current population exposure to traffic emissions in Mexican cities, highlighting the importance of effective policies to mitigate the impact of TRAP on public health.



Global Integration Index for all roadways: Querétaro

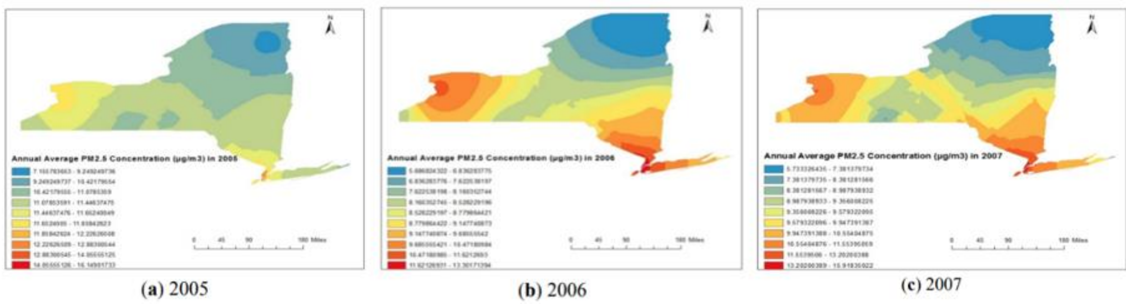


Exposure “hotspots” in a 500 m buffer from the selected corridors: Querétaro

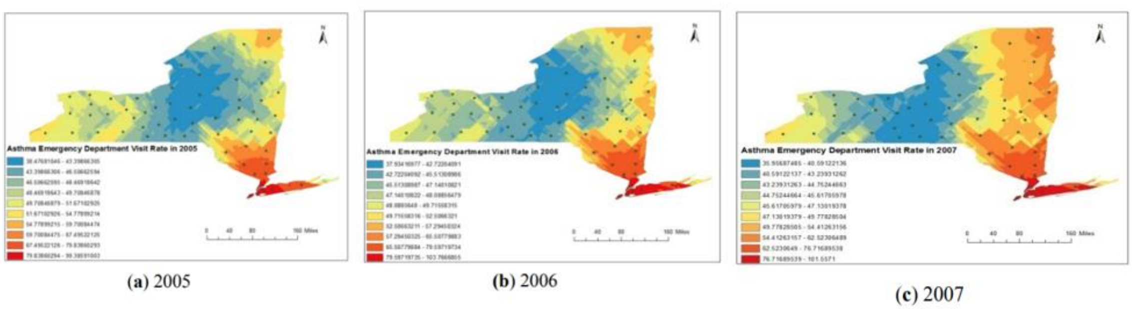


The ten most integrated streets in each of the selected cities

Amit K. Gorai (2014) explored the relationship between air pollution, specifically PM2.5, SO2, and ozone, and health problems among residents of New York State between 2005 and 2007. The study found that there were different associations between the annual mean concentrations of these pollutants and the annual rates of asthma discharge and emergency department visits. Specifically, a positive correlation was observed between PM2.5 and SO2 and health problems, while a negative correlation was observed between ozone and health problems. The study suggests that there is a plausible and significant association between elevated concentrations of PM2.5 and SO2 and health problems among residents of New York State. The findings of this study have important implications for public health policy and air pollution control measures aimed at reducing the prevalence of asthma among residents of urban areas.

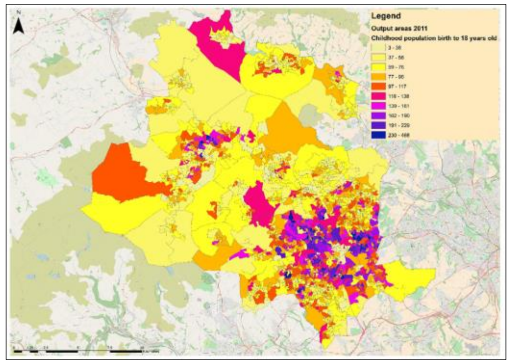


Spatial distribution of annual average 24 h PM2.5 concentrations during 2005 to 2007.

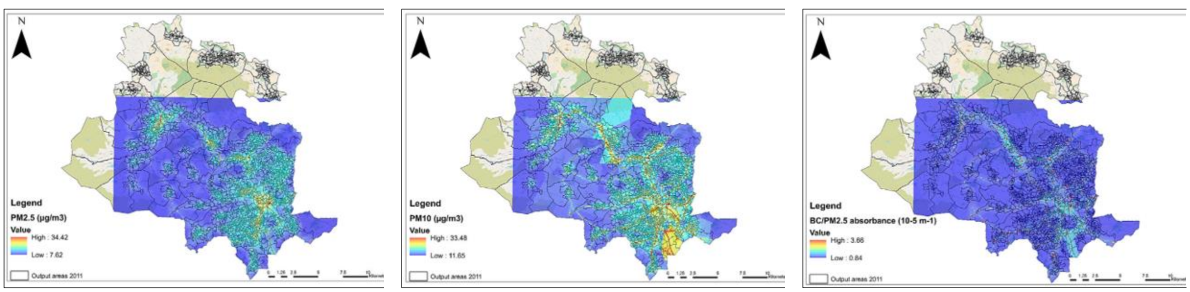


Spatial distribution of asthma emergency department visits rate (AEVR) during 2005 to 2007

Haneen Khreis (2019) aimed to estimate the burden of childhood asthma attributable to traffic-related air pollution (TRAP) using a land-use regression model in Bradford, UK. The study estimated the childhood population's exposure to three air pollutants: PM2.5, PM10, and black carbon (BC), and used meta-analytic exposure-response functions to calculate the relative risk, population attributable fraction of childhood asthma in association with each pollutant, and the number of childhood asthma cases attributable to each pollutant. The results showed that between 15% and 33% of all childhood asthma cases in the city were attributable to air pollution, with 7% and 12% of cases being specifically attributable to TRAP. Compliance with the WHO air quality guidelines prevented up to 29 cases. The study underscores the importance of reducing TRAP levels to improve public health.



Bradford's Census Output Areas and Childhood Population



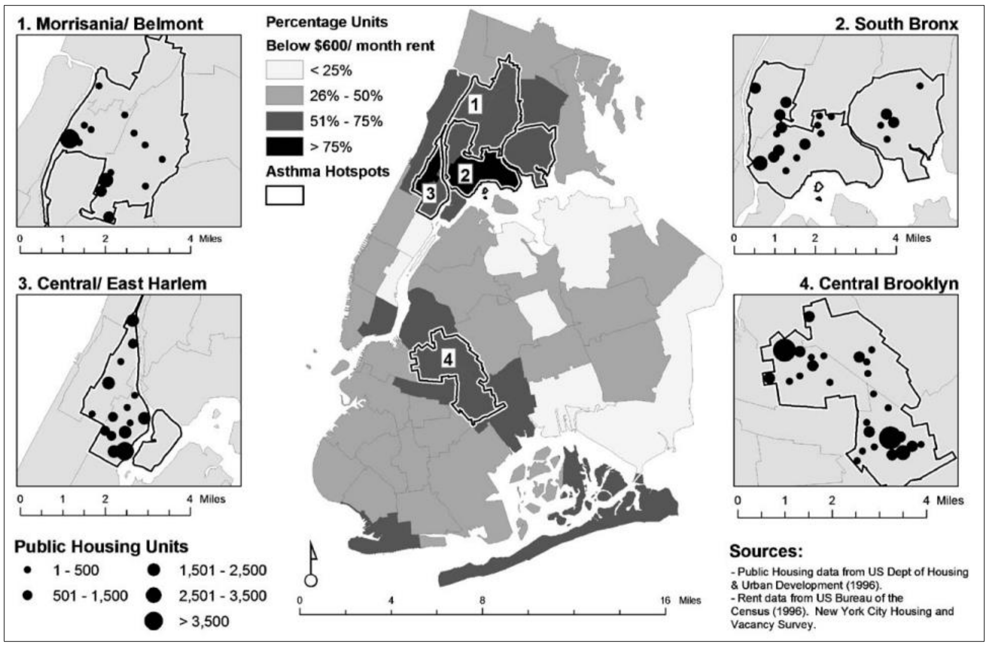
PM2.5, PM10 and BC Spatial Distribution across Bradford (100 m air pollution raster surfaces)

Environmental problems and health problems:

Christian Romero Mesones (2022) examined the impact of environmental factors on asthma characteristics, noting that over 350 million people worldwide suffer from bronchial asthma. A study comparing health problems and clinical presentation between rural and urban populations found that there were no significant differences in health problems, but notable differences in clinical characteristics. There was a higher rate of asthma diagnosis in urban populations, as well as allergies, medication use, emergency room visits, and exacerbations, which were exacerbated by irritants and pollution. In rural populations, however, occupational exposures to dust and animals are more common and are likely to cause respiratory problems.

Corinne Keet's (2015) study examined the effects of urban residence, poverty, race/ethnicity, and household income on the prevalence of childhood asthma in inner-city and non-inner-city areas in the United States. The study utilized data from the National Health Interview Survey (NHIS) for 2009-2011 and included over 23,000 subjects aged 6-17 from 5,853 different census tracts. Findings indicated that neighborhood poverty was associated with higher asthma rates, with household income playing a significant role. The results of this study indicate that the prevalence of asthma was higher in inner-city neighborhoods at first, but the difference decreased after adjusting for demographic factors, suggesting that racial and ethnic factors were the primary determinants of health problems disparities. In spite of poverty and urban/rural status, blacks and Puerto Ricans have higher asthma rates than other racial/ethnic groups. A significant independent predictor of health problems was household poverty, particularly among non-Hispanics and Puerto Ricans. In conclusion, the study revealed a complex interplay between socio-economic and demographic factors in shaping health problems and morbidity, challenging prevailing conceptions about the prevalence of asthma in inner cities.

The focus of Jason Corburn's (2006) study on urban asthma in America is on disadvantaged populations, particularly poor, African American, and Latino children living in urban neighborhoods. The study examines a number of risk factors associated with asthma, including environmental tobacco smoke, indoor allergens, and outdoor air pollutants. By utilizing GIScience methods, this study aims to identify neighborhoods in New York City with high asthma hospitalization rates and develop targeted asthma management and prevention policies through mapping the spatial distribution of social and physical characteristics impacting population health. The findings of this study reveal four primary hotspots of high asthma hospitalization rates in communities with lower median household incomes, higher poverty rates, and a higher percentage of African American and/or Latino residents. Specifically, the study emphasizes the importance of an ecological approach to health, emphasizing that vulnerability and resistance factors operate simultaneously at multiple levels and that material and social resources contribute to disease disparities.



Neighborhood asthma hotpots, average rent, and public housing in New York City

Rodriguez et al. (2019) conducted a systematic review to address an increasing prevalence of asthma and related allergic disorders, particularly in low and middle-income countries (LMICs), which demonstrate a similar trend even in urban areas. According to the study, urbanization is a potential contributor to this trend, but methodological limitations restrict the evaluation of its effects. It is suggested that social inequalities, economic disparities, and poverty are significant determinants of health problems within or between cities. The article recommends that approaches to assessing the relationship between asthma and urbanization in LMICs be enhanced, advocating for more specific causal models and standardized definitions to facilitate epidemiological studies and international comparisons. The findings emphasize the importance of developing targeted public health policies and interventions for LMICs facing the challenges of urbanization and asthma.

Shuvashish Kundu's (2014) study examined the composition and sources of fine particulate matter (PM2.5) in urban and rural areas of the Midwestern United States. There are significant health risks associated with air pollution, particularly PM2.5, and an understanding of its chemical composition is imperative for assessing these risks. The study utilized statistical methods and source identification modeling in order to analyze the PM2.5 concentrations and compositions at five monitoring sites in Iowa between 2009 and 2012. There was a significant difference between PM2.5 levels in rural areas and urban areas, with different chemical compositions reflecting industrial activity in urban areas and natural sources in rural areas. The most common sources of PM2.5 were secondary sulfate, nitrate, biomass burning, and vehicular emissions, with industrial factors only being identified in urban settings. The study also highlights the significant role secondary aerosols and biomass burning play in ambient PM pollution in rural settings in the midwestern United States.

Shan Liu (2022) examined the health risks associated with urban particulate matter pollution and re-suspended fugitive dust in high-speed developing cities such as the Wuhan metropolitan area in China. The study identified various sources of fugitive dust, such as soil, landfills, roads, construction sites, and deposit dust, which may contain heavy metals posing health risks. A chemical analysis of 130 dust samples revealed that heavy metal contamination varies, with some metals being attributed to human activity and others being attributed to natural sources. A positive matrix factorization (PMF) identified local deposition, traffic emissions, fossil fuel combustion, and natural sources as the primary sources of heavy metal contamination. Despite the non-carcinogenic risks associated with heavy metals, chromium carries unacceptable carcinogenic risks for both children and adults. When re-suspended, road dust and deposit dust exhibited relatively higher carcinogenic risks than other types of dust. The findings of this study highlight the importance of comprehensive research on fugitive dust and its health effects, particularly in fast-growing urban areas.

Stefania Squizzato (2017) investigated the effects of a variety of emission sources on PM2.5 concentrations and composition in Treviso, Italy, a region characterized by dense urbanization and human activity. The study aims to identify the sources affecting PM2.5 concentrations and compositions across multiple scales by comparing sampling sites within and outside of the airport boundary. According to the study, residential heating, manufacturing industries, and road transport are significant contributors to PM2.5 pollution in Treviso using various analytical techniques, including non-parametric tests and positive matrix factorizations. As a result of low wind speeds and temperature stability during winter, particulate matter concentrations are exacerbated, particularly ammonium nitrate formation, leading to poorer air quality. As a result of the study, six primary sources of PM2.5 have been identified, including biomass burning, industrial emissions, and road dust resuspension, which provide valuable information for developing effective air quality management policies in smaller urban areas such as Treviso, Italy.

Sofowote et al. (2021) emphasized the importance of monitoring PM2.5 concentration and composition in urban environments, particularly in Toronto, Canada, due to its association with adverse health outcomes. The study aimed to identify the sources of PM2.5 and their variations across different urban locations by combining enhanced source apportionment analyses with site characteristics and meteorological variables. According to the study, traffic-adjacent emissions contribute the most to PM2.5 pollution through the collection and analysis of data from two sampling sites equipped with various instruments. However, there is a difference in the chemical composition of particles depending on where they are located. In urban background areas, local factors such as brake dust dominate while regional factors like pSO4 and pNO3 play a significant role. As a result of the study, it is underscored how important it is to continue monitoring and reducing PM2.5 pollution and protecting public health, highlighting the complexity of intra-city variability of PM2.5 composition and the continued relevance of non-tailpipe emissions for air pollution in urban areas.

Liao, Ho-Tang (2022) investigated the vertical distribution of PM2.5 in Taipei, Taiwan, amid concerns about poor air quality as a result of rapid urbanization. The study collects PM2.5 samples from six different floor levels in a tall building facing a major road from October to December 2020 and analyzes them for trace elements, water-soluble inorganic ions, and organic carbon. Through the use of Positive Matrix Factorization (PMF), the study identified the major sources of PM2.5, including secondary aerosol, biomass burning/industry, and transportation-related emissions. Furthermore, six factors, such as soil dust and sea salt, have been identified as contributing to PM2.5. As a result of the study, the health risks associated with PM2.5, specifically water-soluble organic carbon (WSOC), have been highlighted, highlighting the necessity of understanding the sources of PM2.5 for effective pollution control strategies in urban areas.

Table of variables

Variables	Description	Sources	Mean (S.D.)
Exposure Indicator			
PM2.5 (Concentration)	Percentage of Annual mean concentration of PM2.5 (weighted average of measured monitor concentrations and satellite observations, µg/m3), over three years (2015 to 2017)	California Air Resources Board	94.22 (6.83)
Diesel PM (Concentration)	Annual mean concentration of diesel over three years (2015 to 2017)	California Air Resources Board	0.29 (0.35)
Sensitive Population Indicators			
Asthma (Rate per 10,000)	Spatially modeled, age-adjusted rate of ED visits for asthma per 10,000 (averaged over 2015-2017).	Tracking California	52.14 (39.41)
Low Birth Weight (Percent)	Percent low birth weight, (averaged over 2009-2015).	The Office of Environmental Health Hazard Assessment	4.89 (1.64)
Cardiovascular Disease (Hearth attacks per 10,000)	Spatially modeled, age-adjusted rate of emergency department (ED) visits for AMI per 10,000 (averaged over 2015-2017).	The Office of Environmental Health Hazard Assessment	10.69 (3.93)

Table of variables (Cont.)

Variables	Description	Sources	Mean (S.D.)
Socioeconomics Factor Indicators			
Educational Attainment -No Schooling (Percent)	Percentage of the population over age 25 with less than a high school education (5-year estimate, 2015-2019) from American Community Survey (ACS)	American Community Survey (ACS)	5.16 (5.58)
Poverty (Percent)	Percent of the population living below two times the federal poverty level (5-year estimate, 2015-2019). from American Community Survey (ACS)	American Community Survey (ACS)	20.29 (13.52)
Unemployment (Percent)	Percentage of the population over the age of 16 that is unemployed and eligible for the labor force. Excludes retirees, students, homemakers, institutionalized persons except prisoners, those not looking for work, and military personnel on active duty (5-year estimate, 2015-2019) from American Community Survey (ACS)	American Community Survey (ACS)	4.56 (2.69)

As air pollution from traffic has become a significant issue worldwide due to its potential adverse effects on public health. The purpose of this study is to investigate the complex relationship between traffic-adjacent air pollutants and health problems. The study employs the Statistical Analysis in SPSS program such as Principal Component Analysis (PCA) and Factor Analysis (FA) to analyze various variables, such as traffic pollution (measured by PM2.5 and diesel particulate matter), Socioeconomics factors (such as education, poverty, and unemployment), and health outcomes (asthma, low birth weight, and cardiovascular issues). Also, ArcGIS Pro is used to visualize the analyzed data in order to emphasize the relationship between the variables.

Methodology:

Data Collection

A comprehensive dataset was gathered on air pollution levels, Socioeconomics indicators, and health outcomes. This dataset spans a specific geographical area and time period to ensure the relevance of findings.

Data Analysis with SPSS

The collected data was imported into SPSS for statistical analysis. Descriptive statistics, correlation analysis, and regression models were employed to explore the relationships between variables. The analysis of the data using SPSS has revealed several key findings:

Correlations: Initial correlation analysis suggests significant positive associations between high levels of traffic-adjacent air pollutants (PM2.5 and diesel particulate matter) and adverse health outcomes, particularly asthma, low birth weight, and cardiovascular issues. Socioeconomics variables such as low education, poverty, and unemployment show a notable relationship with health outcomes, potentially acting as confounding factors.

Multiple Regression: Multiple regression analysis is being analyzed in order to control confounding variables and determine whether traffic air pollution directly affects health outcomes.

Data Visualization with ArcGIS Pro

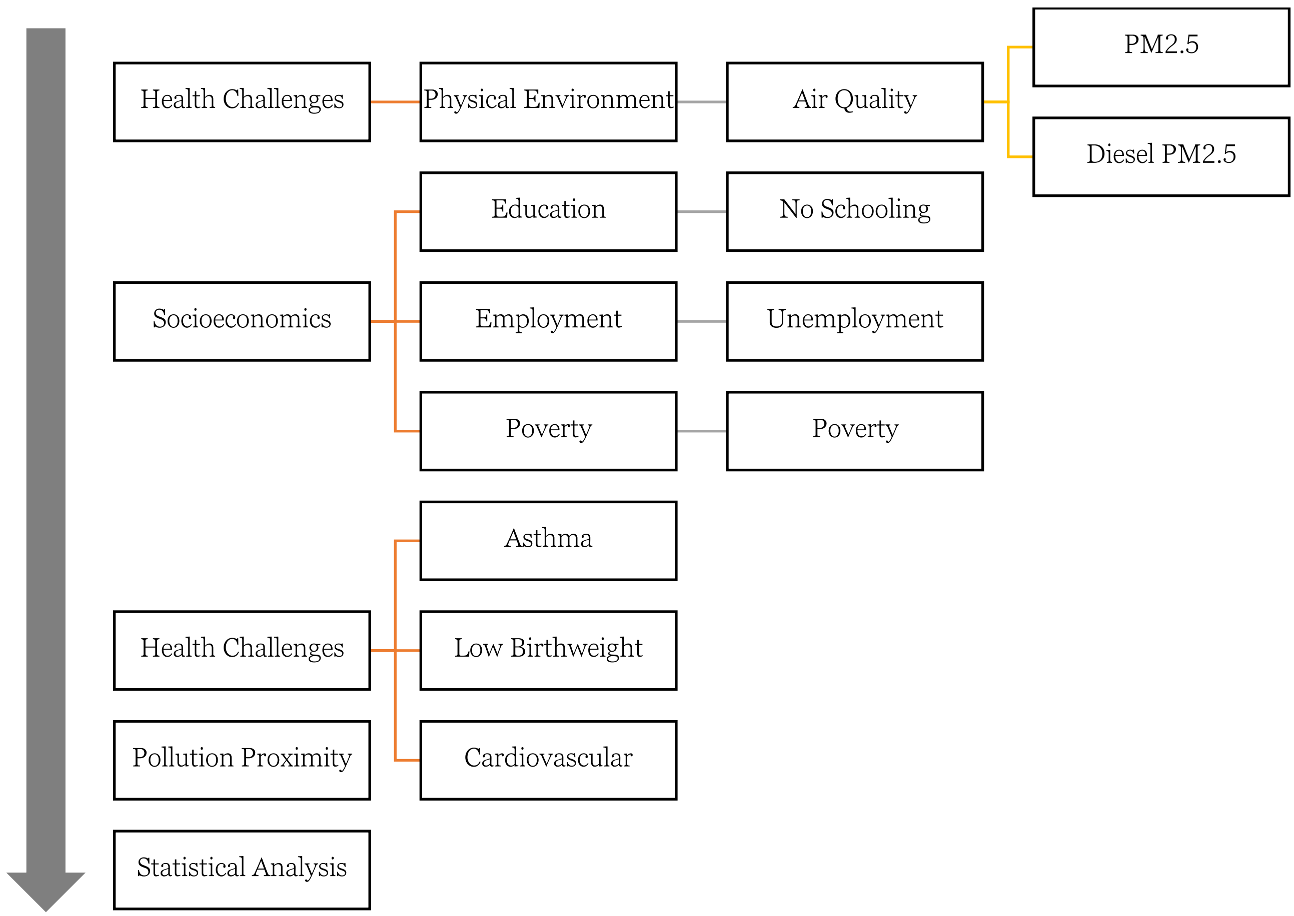
Employing the Near tool in geoprocessing tools proves invaluable for measuring distances between population centroids and the nearest highways. This integrated approach facilitates a comprehensive assessment of spatial relationships, enabling the quantification of proximity between key demographic centers and transportation infrastructure. By leveraging the Near tool within geoprocessing workflows, we can precisely calculate distances, providing crucial insights into the accessibility and connectivity of populated areas to major road networks. As well as the data was processed using ArcGIS Pro to produce bivariate maps that visually represent correlations among variables.

Using statistical tools in combination with ArcGIS Pro enhances our understanding of the data by providing spatially relevant interpretations and gains a comprehensive understanding of how the dataset moves, enabling us to derive actionable insights and drive impactful change.

Study Area

The study focused on the San Francisco Bay Area in California, which is known for high levels of traffic-adjacent air pollution. The study area was defined as the nine counties in the San Francisco Bay Area, including Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma counties.

Impact of Traffic Air Pollution: Factors and Outcomes



Analytical Approaches

As part of the investigation, statistical methodologies were utilized to assess the relationship between traffic-adjacent air pollution and health problems in the San Francisco Bay Area.

Both Principal Component Analysis (PCA) and Factor Analysis (FA) are widely used dimensionality reduction techniques in data analysis, particularly for environmental data such as pollution data. These two methods share some similarities; however, they serve slightly different purposes, providing valuable insight into the relationships between variables. (Reid Ewing, 2020)

PCA (Principal Component Analysis):

The PCA method is primarily used to reduce data dimensionality while preserving original variance. It has also been successfully applied to pollution data variables (e.g., PM2.5 and Diesel PM) to identify patterns and relationships. In addition, it can analyze geographical coordinates in order to identify spatial patterns or clusters. By examining pollution data, PCA identifies common pollution sources and correlations between pollutants, revealing co-occurrence patterns or associations with particular regions.

FA (Factor Analysis):

The FA method is used to reveal latent factors underlying observed variables. It assumes that observed variables are the result of a combination of unobserved factors and error terms. As a result of FA, pollution data can be identified as having unobservable sources of pollution as well as hidden variables. As a result, it allows for a deeper understanding of pollution causes and determines whether observed variables (such as pollutant concentrations) can be explained by a smaller number of latent factors.

As a result, PCA and FA appear to be applicable to pollution data with positive outcomes, suggesting that these methods are useful for analyzing and understanding pollution data, as well as contributing to the development of a comprehensive understanding of environmental pollution and mitigation strategies. Positive outcomes (Frances Chumney, 2012) include:

1. Identifying Pollution Sources: Understanding patterns and relationships among pollutants facilitates the identification of major pollution sources.

2. Reducing data dimension: Reducing pollution data complexity facilitates interpretation and visualization.

3. Correlation Analysis: Quantify relationships between variables, such as pollutant correlations or geographical factors which affect pollution levels.

4. Analysis of pollution drivers: Knowing what drives pollution, whether it is industrial activity, traffic, climate conditions, or a combination of factors.

Results

Pollution Data:

A Principal Component Analysis (PCA) and Factor Analysis (FA) can be performed on pollution data collected from diverse sources, incorporating variables such as particulate matter (PM2.5), diesel PM, and geographic coordinates.

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
PM2.5	94.22	6.833	1581
Diesel PM	-1.7914	1.17102	1581

Correlation Matrix

		PM2.5	Diesel PM
Correlation	PM2.5	1.000	.432
	Diesel PM	.432	1.000

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.500
Bartlett's Test of Sphericity	Approx. Chi-Square	326.386
	df	1
	Sig.	<.001

Anti-image Matrices

		PM2.5	Diesel PM
Anti-image Covariance	PM2.5	.813	-.351
	Diesel PM	-.351	.813
Anti-image Correlation	PM2.5	.500[a]	-.432
	Diesel PM	-.432	.500[a]

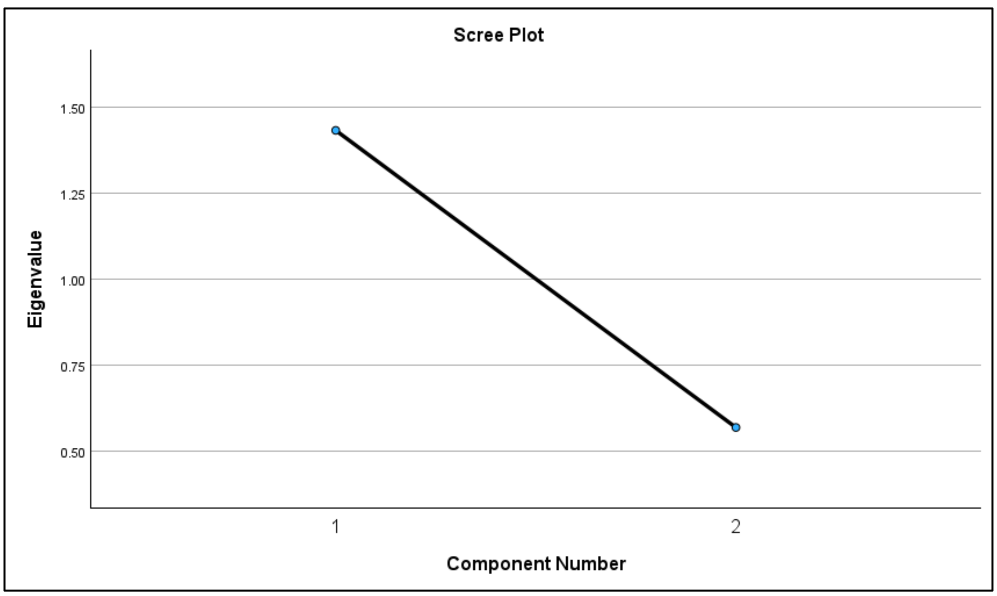
a. Measures of Sampling Adequacy (MSA)

Communalities		
	Initial	Extraction
PM2.5	1.000	.716
Diesel PM	1.000	.716

Extraction Method: Principal Component Analysis.

Total Variance Explained						
	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.432	71.610	71.610	1.432	71.610	71.610
2	.568	28.390	100.000			

Extraction Method: Principal Component Analysis.



Component Matrix[a]	
	Component
	1
PM2.5	.846
Diesel PM	.846

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

The analysis reveals moderate positive correlations among the variables PM2.5 and Diesel PM, as demonstrated by the correlation matrix. The Kaiser-Meyer-Olkin (KMO) value, indicating moderate sampling adequacy, suggests that the dataset is suitable for further factor analysis. Bartlett's Test of Sphericity supports this, affirming the intercorrelation of variables. Principal Component Analysis (PCA) also reveals insightful results, with one dominant component explaining a substantial portion of the overall variance. The loadings in the component matrix indicate comparable contributions from PM2.5 and Diesel PM to this extracted component. Based on these findings, we are able to provide a comprehensive understanding of the interrelationships and shared variance between variables, particularly when viewed in the context of the primary component identified in the PCA.

Health Data:

Data on health outcomes, such as asthma, low birth weight, and cardiovascular disease, is often included in health data as these outcomes are directly and indirectly impacted by air pollution.

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
Asthma	52.38	39.384	1556
Low Birth Weight	4.89	1.648	1556
Cardiovascular	10.73	3.937	1556

Correlation Matrix

		Asthma	Low Birth Weight	Cardiovascular
Correlation	Asthma	1.000	.323	.787
	Low Birth Weight	.323	1.000	.260
	Cardiovascular	.787	.260	1.000

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.556
Bartlett's Test of Sphericity	Approx. Chi-Square	1673.693
	df	3
	Sig.	<.001

Anti-image Matrices				
		Asthma	Low Birth Weight	Cardiovascular
Anti-image Covariance	Asthma	.365	-.114	-.287
	Low Birth Weight	-.114	.896	-.005
	Cardiovascular	-.287	-.005	.380
Anti-image Correlation	Asthma	.534[a]	-.199	-.770
	Low Birth Weight	-.199	.812[a]	-.009
	Cardiovascular	-.770	-.009	.537[a]

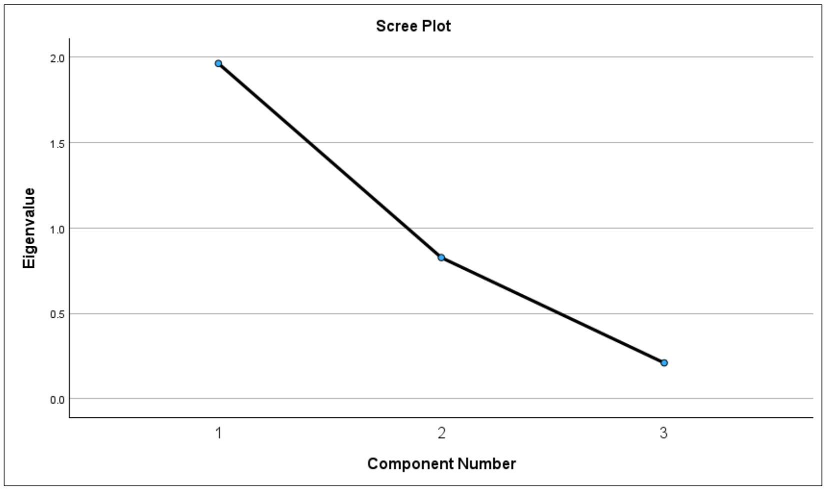
a. Measures of Sampling Adequacy (MSA)

Communalities		
	Initial	Extraction
Asthma	1.000	.848
Low Birth Weight	1.000	.304
Cardiovascular	1.000	.812

Extraction Method: Principal Component Analysis.

Total Variance Explained						
	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.964	65.459	65.459	1.964	65.459	65.459
2	.826	27.550	93.009			
3	.210	6.991	100.000			

Extraction Method: Principal Component Analysis.



Component Matrix[a]	
	Component
	1
Asthma	.921
Low Birth Weight	.552
Cardiovascular	.901

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

In summary, the health data analysis reveals substantial correlations among the health outcomes, with Asthma exhibiting strong positive correlations with both Low Birth Weight and Cardiovascular conditions. The Kaiser-Meyer-Olkin (KMO) measure suggests moderate sampling adequacy, and Bartlett's Test supports the suitability of the data for factor analysis. Principal Component Analysis (PCA) indicates that one dominant component explains a significant portion of the variance, with loadings from Asthma, Low Birth Weight, and Cardiovascular conditions contributing meaningfully to this component. These findings offer a comprehensive understanding of the relationships and shared variance among the health variables.

Socioeconomics Data:

Socioeconomics data encompasses variables like unemployment, poverty, and education attainment particularly no schooling.

Descriptive Statistics			
	Mean	Std. Deviation	Analysis N
Poverty	20.19	13.447	1521
Unemployment	4.57	2.691	1521
No Schooling	2.50	2.801	1521

Correlation Matrix				
		Poverty	Unemployment	No Schooling
Correlation	Poverty	1.000	.516	.519
	Unemployment	.516	1.000	.278
	No Schooling	.519	.278	1.000

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.597
Bartlett's Test of Sphericity	Approx. Chi-Square	947.527
	df	3
	Sig.	<.001

Anti-image Matrices				
		Poverty	Unemployment	No Schooling
Anti-image Covariance	Poverty	.581	-.296	-.297
	Unemployment	-.296	.733	-.010
	No Schooling	-.297	-.010	.731
Anti-image Correlation	Poverty	.565[a]	-.453	-.456
	Unemployment	-.453	.626[a]	-.014
	No Schooling	-.456	-.014	.625[a]

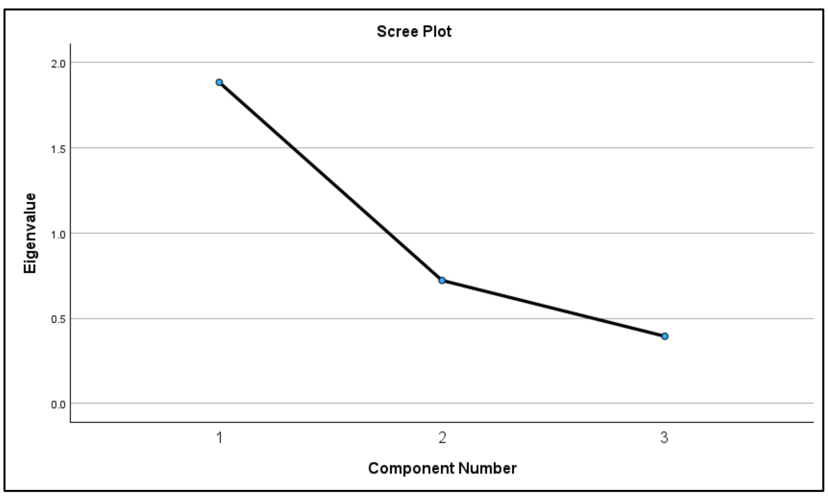
a. Measures of Sampling Adequacy (MSA)

Communalities		
	Initial	Extraction
Poverty	1.000	.766
Unemployment	1.000	.558
No Schooling	1.000	.561

Extraction Method: Principal Component Analysis.

Total Variance Explained						
	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.884	62.813	62.813	1.884	62.813	62.813
2	.722	24.055	86.868			
3	.394	13.132	100.000			

Extraction Method: Principal Component Analysis.



Component Matrix[a]	
	Component
	1
Poverty	.875
Unemployment	.747
No Schooling	.749

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

In summary, the analysis indicates notable correlations among Unemployment, Poverty, and No Schooling. The Kaiser-Meyer-Olkin (KMO) measure suggests moderate sampling adequacy, and Bartlett's Test supports the suitability of the data for factor analysis. The Principal Component Analysis (PCA) results reveal that one dominant component explains a significant portion of the variance, with strong loadings from all three variables contributing meaningfully to this component. These findings offer insights into the shared variance and interrelationships among the Socioeconomics factors under consideration.

Correlation Coefficients

Model Summary

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.568[a]	.323	.322	.81940585	.323	359.807	2	1511	<.001

a. Predictors: (Constant), Traffic Pollution, Socioeconomics

As shown in the summary table, the R-value of the model is .568, which indicates a moderate correlation between the independent variables (Traffic Pollution and Socioeconomics) and the dependent variable (Health Challenges). The R Square (R^2) for the dependent variable is 0.323, which indicates that approximately 32.3% of the variance in the dependent variable (Health Challenges) can be explained by the independent variables (Traffic Pollution and Socioeconomics). This indicates that a substantial part of the relationship between Traffic Pollution and Socioeconomics Factors and Health Challenge outcome can be explained by the model. While the R square and adjusted R square values do not differ significantly (.323 and .322, respectively), it is reasonable to conclude that the independent variables included in the model are relevant and contribute significantly to explaining the variance in Health Challenges.

Coefficients[a]								
		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
Model		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
1	(Constant)	-.002	.021		-.091	.928	-.043	.039
	REGR Traffic Pollution	.537	.022	.535	23.910	<.001	.493	.581
	REGR Socioeconomics	.087	.023	.085	3.784	<.001	.042	.132

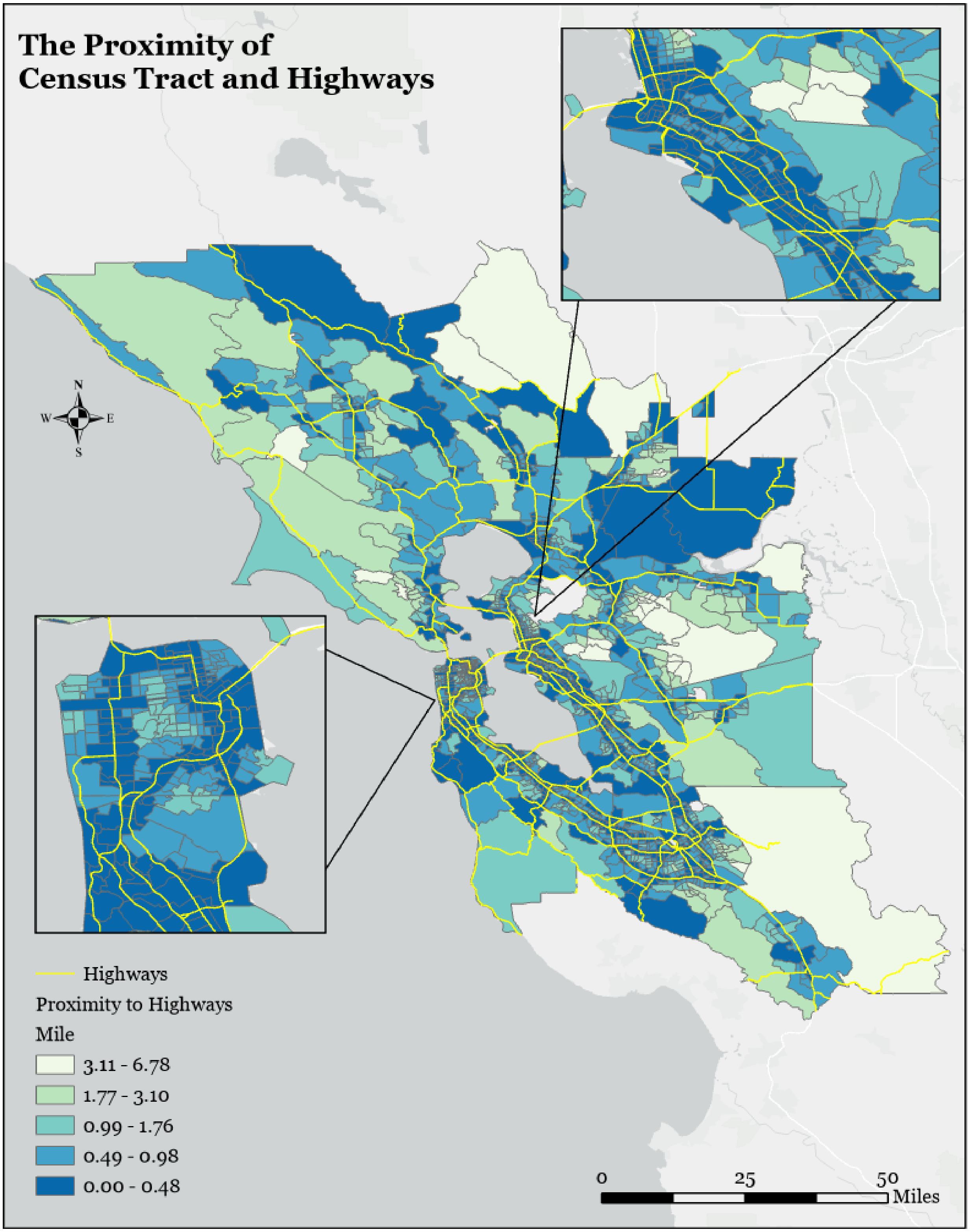
a. Dependent Variable: Health Challenges

According to the Coefficients Table, both traffic pollution and Socioeconomics factors are statistically significant contributors to health challenges. In both cases, the significant value for Traffic Pollution and Socioeconomics is expressed at .001, which indicates a high level of confidence (greater than 99%) that these factors are significant factors associated with health challenges. In addition, there was a standardized coefficient of .535 and .085 for Traffic Pollution and Socioeconomics, respectively, which indicate that Health Challenges increases by a standard deviation of .535 and .085 for each standard deviation increase in Traffic Pollution and Socioeconomics. However, the above number indicates that Traffic Pollution has a greater impact on Health Challenges than Socioeconomics, as Traffic Pollution has a significantly larger standardized coefficient (0.535) than Socioeconomics (0.085), indicating that Traffic Pollution significantly impacts Health Challenges.

Findings

The areas that are located near highways play a significant role in determining the degree of exposure to poor air quality among their residents. It is important to note that proximity is a crucial factor that can measure a negative impact on air quality within communities. Using geoprocessing tools, in particular the "Near" tool, provides an effective means of quantifying and evaluating spatial correlations. This tool allows us to obtain valuable insights into the level of pollution exposure experienced by residents in specific locations by measuring the distance between population centroids and the closest highways.

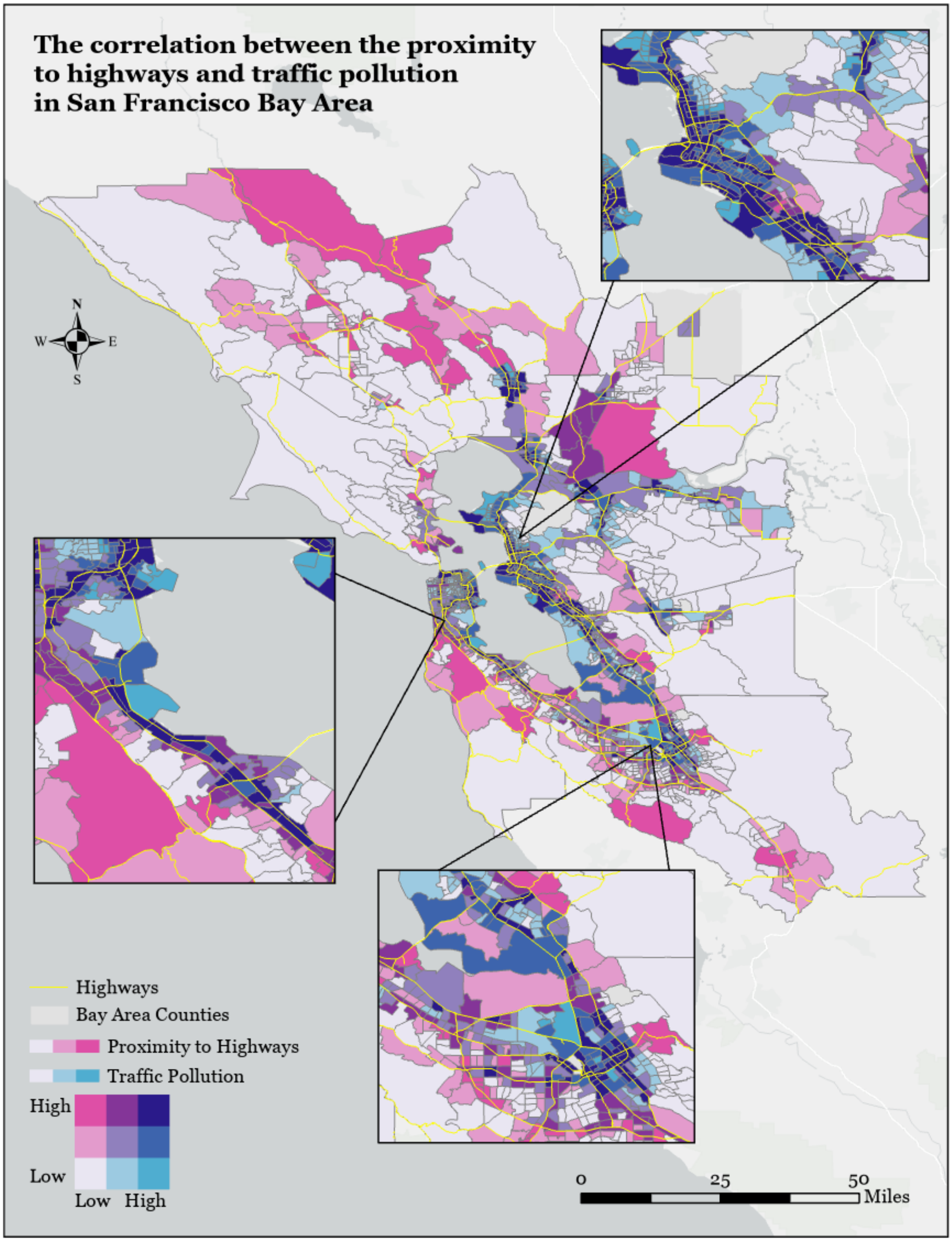
In the Near tool, a spatial framework is established that illustrates the close connection between population centroids and major roads, facilitating an assessment of the impact of this proximity on air quality. It can be beneficial to make informed decisions regarding urban planning, public health interventions, and environmental management when the proximity of population centroids to highways can be assessed using geoprocessing tools. As a result of such efforts, air pollution adversely affects a wide range of population groups who are vulnerable to it.



The Proximity of Population Centroids of each Census Tracts to the Nearest Highways

The examination of air traffic pollution, specifically the concentration of pollutants such as PM2.5 and Diesel PM, reveals a distinct relationship in census tracts intersected by highways. A significant portion of this correlation can be found in areas adjacent to one of the busiest highways in the Bay Area, namely I-880 around East Bay, San Jose, and Highway 101 in South San Francisco. High levels of air pollution have been observed in these specific regions in correlation with the presence of major highways. It is clear from the elevated concentrations of pollutants in census tracts adjacent to highways that vehicles and traffic-related factors have a significant impact on the quality of the air in these areas. In areas heavily influenced by high traffic volumes, this spatial relationship is imperative for understanding the localized environmental dynamics and for developing targeted interventions to mitigate air pollution's adverse effects. Acknowledging these spatial patterns is crucial for effective urban planning, environmental policies, and public health strategies developed to address the challenges caused by traffic-adjacent air pollution in specific regions.

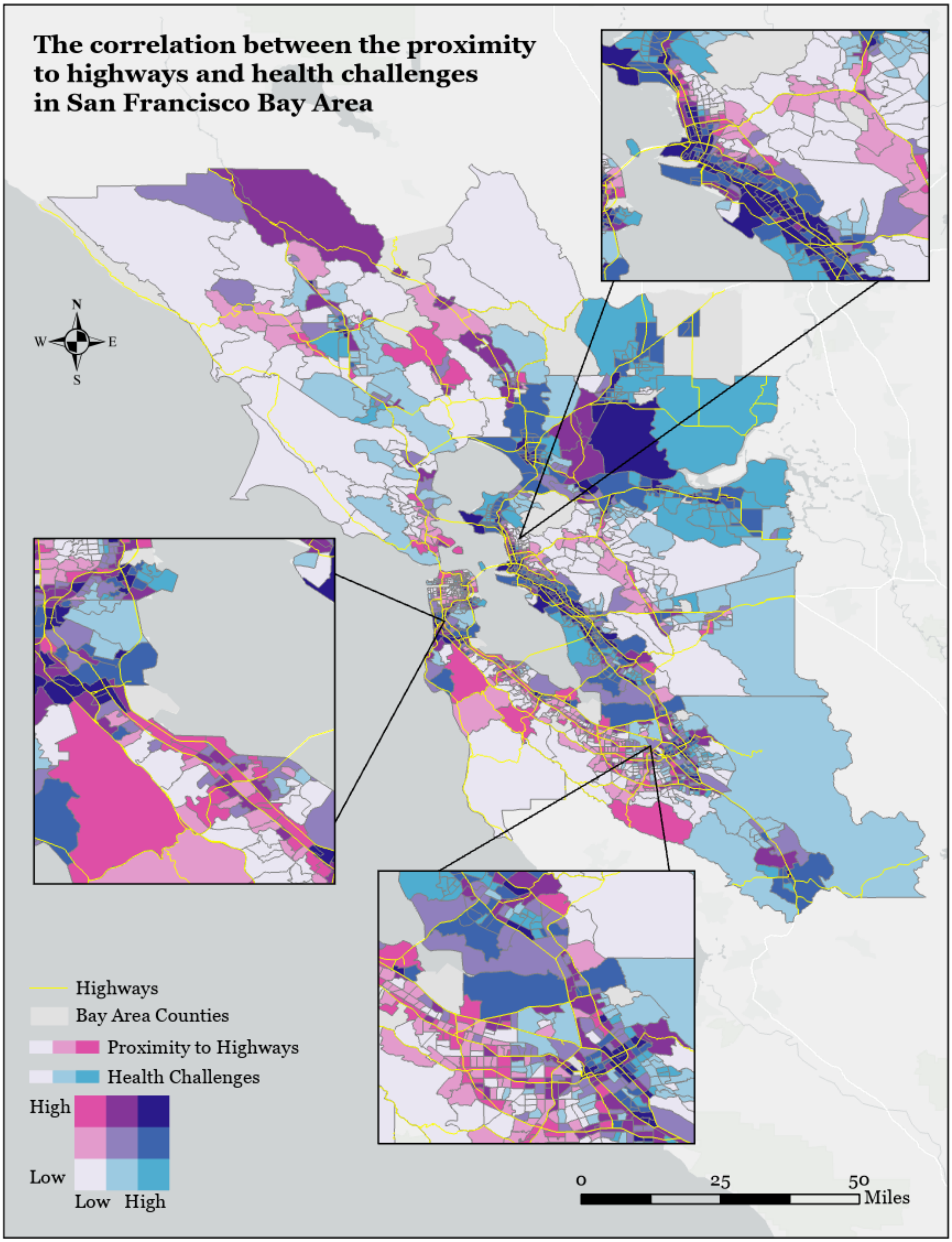
The outcomes of the Principal Component Analysis (PCA) in the statistical analysis of our dataset reveal a positive relationship among the variables under consideration. Upon further examination of the data, it becomes evident that certain health variables are positively correlated with one another, indicating potential interconnections related to health outcomes. In particular, this analysis reveals a significant association when pollution proximity to highways is taken into consideration. As a result of PCA, a positive relationship has been identified that aligns with the heightened pollution exposure near highways, emphasizing the importance of this environmental factor in understanding health outcomes. This integrated analysis underscores the interconnected nature of health variables and their relationship with environmental factors, especially the proximity of populations to highways, thus providing an understanding of a comprehensive health landscape influenced by both intrinsic health factors and external environmental factors.



The Relationship between Proximity to Highways and Traffic Pollution in San Francisco Bay Area

The examination of health data within census tracts intersected by highways reveals a positive relationship among health issues such as asthma, low birthweight, and cardiovascular disease. The connection becomes particularly evident around one of the busiest highways in the Bay Area, specifically I-880 around East Bay, Oakland, and San Leandro. The elevated prevalence of these health problems in proximity to this extremely busy highway demonstrates a significant spatial relationship. In this specific region, adverse health outcomes are concentrated in a localized area, suggesting a possible link between these health problems and the environmental factors associated with high traffic levels and pollution levels along I-880. As a result of these findings, it becomes imperative to include the spatial dimension in health analyses, which underscores the need for specific interventions and policies in regions where spatial correlations are evident. By understanding the spatial dynamics associated with health concerns in relation to major highways, we can better strategize for public health. Environmental variables and community welfare play an important role in shaping public health policy.

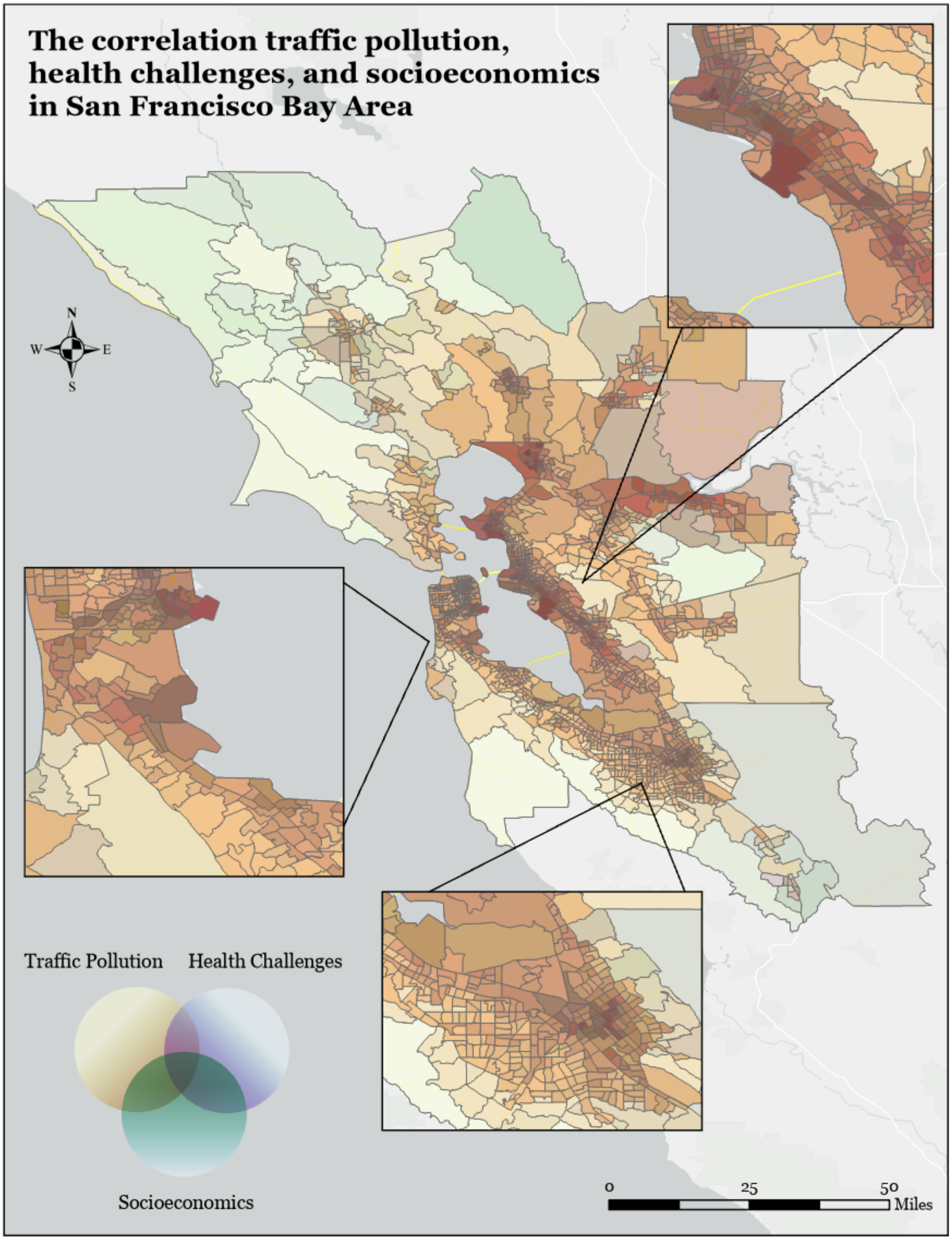
The Principal Component Analysis (PCA) in the statistical analysis reveals a positive relationship between variables related to traffic pollution, specifically the distance to highways and the concentration of air pollution. A correlation is apparent through PCA, indicating that these variables exhibit a coherent pattern of variation. This positive relationship implies that as the distance to highways decreases, there is a corresponding increase in the concentration of air pollution. According to PCA, the strength of this association illuminates the interconnected nature of these factors and provides quantitative insight into how changes in one variable influence changes in the other. As a result of statistical analyses, such insight can assist in clarifying the complexities associated with traffic-adjacent pollution, providing valuable information to urban planning, environmental management, and public health initiatives aimed at mitigating the impact of air pollution near highways.



The relationship between Proximity to Highways and Health Outcomes in San Francisco Bay Area

The final observation, when took Socioeconomics disparities into account, it can be found that lack of education, job opportunities may be limited, and access to health care may be restricted, while unemployment can create financial instability and affect the ability to obtain healthcare. Similarly, poverty exacerbates these challenges, by causing insufficient income, housing, and access to basic services, thus reducing the quality of life and health outcomes. There is evidence of traffic pollution, health challenges, and Socioeconomics disparities are significantly correlated. When the data were analyzed collectively, we found a positive association, indicating that areas with higher levels of traffic air pollution tend to experience higher rates of health problems and Socioeconomics disparities. Additionally, the graphic representation provides evidence of how areas experiencing greater traffic air pollution experience increased numbers of health issues and Socioeconomics disadvantages.

These findings indicate that the problem of traffic-adjacent air pollution requires integrated interventions that consider not only the reduction of emissions but also the socio-economic context of the affected communities. In addition to measures to mitigate air pollution, strategies should be developed to improve access to healthcare, education, and economic opportunities in areas that are disproportionately affected by traffic-related pollution. As a result of addressing these interrelated factors together, policymakers can create more equitable and healthier environments for all residents.



The multivariate map of the relationship between Traffic Pollution, Health Challenges, and Socioeconomics in San Francisco Bay Area

Conclusion

In conclusion, our investigation of the complex relations between traffic air pollution and health challenges has revealed convincing evidence that this phenomenon adversely impacts public health, particularly in areas adjacent to highways. After thorough analysis, it became apparent that these areas experience high levels of traffic pollution, leading to health problems such as asthma, low birth weight, and cardiovascular disease. Additionally, our analysis of Socioeconomics factors revealed another layer of disparities. In regions characterized by low income, lower education rates, and high unemployment rates, health problems associated with increased traffic pollution are disproportionately exacerbated. It is important to note that the intersection of environmental and Socioeconomics factors emphasizes the urgent need for comprehensive strategies aimed at addressing disparities in pollution exposure as well as health outcomes.

Considering these results, policymakers should play an active role in addressing this pressing issue. It is imperative that policymakers prioritize initiatives that will mitigate the negative effects of traffic pollution on vulnerable communities. In order to accomplish this, regulations need to be implemented in order to reduce vehicle emissions. Public transportation infrastructure must be developed in order to reduce the need for private vehicles, and land use planning strategies must be implemented to decrease exposure in high-risk areas. Moreover, policymakers should prioritize efforts to address fundamental Socioeconomics indicators of health, such as poverty and unemployment. By promoting economic empowerment, access to education, and affordable healthcare, we can create an environment in which individuals can lead healthy lives.

Therefore, in order to address the complex connection between traffic air pollution, Socioeconomics factors, and health challenges, a comprehensive approach is required, involving stakeholders from various sectors. To achieve this goal, we must collaborate effectively and implement evidence-based policies aimed at improving community health and resilience for present and future generations.

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