# STRUCTURAL DISPARITIES OF URBAN TRAFFIC IN SOUTHERN CALIFORNIA: IMPLICATIONS FOR VEHICLE-RELATED AIR POLLUTION EXPOSURE IN MINORITY AND HIGH-POVERTY NEIGHBORHOODS

DOUGLAS HOUSTON*
JUN WU
PAUL ONG
ARTHUR WINER
*University of California, Los Angeles*

**ABSTRACT:** *Structural inequalities provide an important context for understanding and responding to the impact of high traffic densities on disadvantaged neighborhoods. Emerging atmospheric science and epidemiological research indicates hazardous vehicle-related pollutants (e.g., diesel exhaust) are highly concentrated near major roadways, and the prevalence of respiratory ailments and mortality are heightened in these high-traffic corridors. This article builds on recent findings that low-income and minority children in California disproportionately reside in high-traffic areas by demonstrating how the urban structure provides a critical framework for evaluating the causes, characteristics, and magnitude of traffic, particularly for disadvantaged neighborhoods. We find minority and high-poverty neighborhoods bear over two times the level of traffic density compared to the rest of the Southern California region, which may associate them with a higher risk of exposure to vehicle-related pollutants. Furthermore, these areas have older and more multifamily housing, which is associated with higher rates of indoor exposure to outdoor pollutants, including intrusion of motor vehicle exhaust. We discuss the implications of these patterns on future planning and policy strategies for mitigating the serious health consequences of exposure to vehicle-related air pollutants.*

Travel provides an essential link between people and social, economic, and recreational activities in metropolitan areas. Despite these benefits to regional prosperity, vehicle travel is increasingly responsible for numerous externalities including heightened congestion, increased noise, and diminished air quality due to vehicle-related pollutants. The distribution of these externalities within the urban environment is deeply embedded within

*Direct Correspondence to: Douglas Houston, The Ralph and Goldy Lewis Center for Regional Policy Studies, School of Public Policy and Social Research, University of California, 3250 Public Policy Building, Los Angeles, California, CA 90095-1656. E-mail: dhouston@ucla.edu

**JOURNAL OF URBAN AFFAIRS, Volume 26, Number 5, pages 565–592.**

**ISSN: 0735-2166.**

the urban structure and related to persistent inequalities such as racial segregation, concentrated poverty, and uneven land use development.

This article documents ways that historic and structural patterns within Southern California provide an important context for understanding the causes, characteristics, and magnitude of traffic, particularly for disadvantaged neighborhoods. We've just begun to understand the health costs of heightened levels of vehicle-related pollutants immediately adjacent to heavily traveled roadways and know little about the demographic and socioeconomic groups exposed to these pollutants. Documenting and quantifying the distribution of traffic density in Southern California is an essential step and prerequisite to understanding potential exposure patterns and in formulating policy and planning interventions that can help minimize the hazardous impact of vehicle-related pollutants.

We begin by discussing the adverse health effects of traffic-related pollutants and current regulatory approaches to improve regional air quality. We then describe the growing evidence that these pollutants and related health impacts are concentrated within hundreds of meters of major roadways. This raises a number of distributional concerns, especially given the uneven distribution of environmental hazards in Southern California. We provide a framework for understanding environmental disparities in the region by identifying geographic patterns of racial segregation and concentrated poverty in Southern California and by documenting the overlap of disadvantaged neighborhoods with regional job centers and the transportation network. We present our finding that minority and high-poverty neighborhoods in the region bear over two times the level of traffic density compared to the rest of the region. We conclude with a discussion of the implications of our findings for environmental justice research and strategies for mitigating the localized impacts of vehicle-related pollutants.

## ADVERSE HEALTH EFFECTS OF VEHICLE-RELATED AIR POLLUTION

Vehicle traffic remains a major and often dominant source of air pollution. In Southern California, on-road mobile source emissions are responsible for about 76% of carbon monoxide (CO), as well as 45% of volatile organic compounds (VOC), and 63% of nitrogen oxides (NOx), the precursors to ozone and other components of photochemical smog (South Coast Air Quality Management District, 2003). The geographic dispersion of these and other vehicle-related pollutants within the region varies based on a number of factors. The concentrations of primary pollutants that are directly emitted into the air are typically highest close to their sources. Secondary pollutants such as ozone are gases or particles not directly emitted into the atmosphere that form in the atmosphere because of chemical reactions of precursor compounds, often driven by sunlight. They tend to reach their highest concentrations some distance downwind from the original emission source. The prevailing daytime sea breeze in Southern California tends to transport pollutants from coastal areas to the inland valleys where secondary pollutants reach their maximum concentration.

A vast body of scientific evidence has documented the adverse health effects of vehicle-related pollutants including chronic illness, lung impairment, and increased morbidity and mortality (Table 1) (American Lung Association, 2002; Hall, Winer, Kleinman, Lurmann, Brajer, & Colome, 1992; South Coast Air Quality Management District, 2003). These adverse health effects have a serious impact on California's economy. In 1998, hospitalization and medication costs for asthma in the state totaled $1.3 billion (Asthma and Allergy Foundation of America, 1998). Exposure to air pollution in the state is responsible for about 2.8 million lost workdays each year and over $3.5 billion in hospitalizations and

**TABLE 1**

**Selected Vehicle-Related Air Pollutants and Related Health Effects**

| Pollutant Group | Sources | Scale | Known Health Effects |
|---|---|---|---|
| Ozone | Photochemical reactions from NOx and VOCs | Regional | Eye and throat irritation; reduced exercise capacity; exacerbation of respiratory disease |
| Fine Particulate Matter (PM10, PM2.5) | Diesel engines and other sources | Local and regional | Upper respiratory tract irritation and infection; exacerbation of and increased mortality from cardiorespiratory diseases |
| Carbon monoxide (CO) | Engine | Very local | Headache, nausea, dizziness, breathlessness, fatigue, visual disturbance, confusion; angina, coma, death; low birthweight (after maternal exposure during pregnancy) |
| Nitrogen oxides (NOx) | Engine | Local and regional | Eye irritation; upper respiratory tract infection (especially in children); exacerbation of asthma; irritation of bronchi |
| Air toxics (e.g., benzene) | Fuel production and engines | Very local | Eye irritation; lung cancer; asthma, cancer |

the treatment of major and minor illnesses (California Air Resources Board, 2003a; California Air Resources Board and California American Lung Association, 2004; California Air Resources Board and California Office of Environmental Health Hazard Assessment, 2002; United States Environmental Protection Agency, 1999). Analysis indicates the benefits of California's air quality program exceeded the costs by a ratio of about 3 to 1 (California Air Resources Board, 2003a).

The federal Clean Air Act (CAA) strives to minimize the health and economic externalities of mobile sources of air pollution by mandating that states achieve regional ambient air quality standards. At the state level, the California Air Resources Board (CARB) pursues conformity with these standards by regulating on-road vehicle emission standards, fuel specifications, some off-road sources, and consumer product standards. At the regional level, the South Coast Air Quality Management District (SCAQMD) is responsible for developing Southern California's Air Quality Management Plan (AQMP) that establishes programs to ensure regional conformance with all federal and state air quality requirements. SCAQMD works closely with the Southern California Association of Governments (SCAG), which coordinates with local city and county governments to ensure that regional transportation investments, programs, and plans demonstrate state and federal attainment with air quality standards. If regional conformity is not attained, the region can be denied billions of dollars in annual federal transportation funds from the Federal Highway Administration (FHWA) or the Federal Transit Agency (FTA).

This regulatory approach has driven measures to improve air quality in Southern California. The region currently meets all air quality standards except for ozone and particulate matter (South Coast Air Quality Management District, 2003). Despite this benefit, this regional strategy may not be sufficient to mitigate the highly localized impacts of vehicle-related air pollutants. Recent field studies indicate the highest exposures to vehicle-related pollutants such as carbon monoxide, particulate matter, and ultra-fine particles are highly localized near major roadways. Depending on meteorological conditions, the concentrations of these pollutants decline to near background levels within 150 to 500 meters of major roadways (Hitchins, Morawska, Wolff, & Gilbert, 2000; Zhu, Hinds, Kim, Sioutas, 2002). Although factors such as wind direction and time allocated to personal activities mediate personal exposure to nearby pollutants, these studies suggest close residential proximity to high-traffic roadways is a fundamental factor in overall human exposure to vehicle-related air pollutants.

At the same time, evidence is rapidly accumulating of a heightened prevalence of respiratory ailments and mortality among subjects living near heavily traveled roadways (see Table 2 for an overview of key studies). Childhood cancer, brain cancer, and leukemia have been positively associated with traffic density. Wilhelm and Ritz (2003) recently reported that women in Los Angeles County with high traffic density within 750 feet of their residence faced increased risk of preterm birth and term low birth weight by as much as 10 to 20%.

By documenting the localized concentration of vehicle-related pollutants and the heightened health effects of these pollutants in high traffic areas, these studies raise serious local health concerns that may be overlooked by the existing regional-scale conformity process. For instance, even though Southern California has met regional air quality standards for carbon monoxide and nitrogen dioxide, levels may be particularly concentrated along heavily traveled roadways or transportation corridors. Regional measures of carbon monoxide and nitrogen dioxide may mask this pattern and preclude a more localized understanding of the health impacts of vehicle-related air pollution. A geographic understanding of local traffic volume is an essential first-step towards estimating the vehicle-related pollutant concentrations and their associated health effects.

## DISTRIBUTIONAL IMPACTS OF ENVIRONMENTAL HAZARDS

The fields of public health and epidemiology have begun to investigate the role that pollution plays in the complex patterns of health disparities among poor and minority populations. As a group, poor and minority individuals tend to have higher rates of asthma prevalence, hospitalization, and mortality (Geronimus, 2000; see Wright & Ficher (2003) for an overview of related studies). Furthermore, emerging research suggests an association between neighborhood environment and health after controlling for individual socioeconomic and other characteristics (Kawachi & Berkman, 2003).

Environmental justice research has established that a relationship exists in the Los Angeles region between a neighborhood's racial and socioeconomic composition and proximity to hazardous air pollution. Minority and low-income areas in the Los Angeles region have borne a disproportionate level of stationary sources of air pollution including hazardous waste storage and disposal facilities (TSDFs) and Toxic Release Inventory (TRI) facilities (Boer, Pastor, Sadd, & Snyder, 1997; Burke, 1993; Lejano & Iseki, 2001; Lejano, Piazza, & Houston, 2002; Maantay, 2002; Pastor, Sadd, & Hipp, 2001; Pastor, Sadd, Morello-Frosch, 2002; Sadd, Pastor, Boer, & Snyder, 1999). Given that mobile sources are the largest contributor of estimated cancer risk from air toxins, more recent work has used a risk assessment approach to examine the distributional impact of mobile sources of air pollution. An SCAQMD study attributes about 70% of carcinogenic risk in Southern California to diesel particulate emissions and 20% to other mobile sources (South Coast Air Quality Management District, 1999). Results from the U.S. Environmental Protection Agency's Cumulative Exposure Project suggest that mobile source emissions from on-road and off-road vehicles are associated with about 70% of

**TABLE 2**

**Key Studies on Air Pollution and Health Effects Near High-Traffic Areas**

| Health Outcome/Study Description | Findings |
|---|---|
| Shorter Life Span. (Hoek, Brunekreef, Goldbohn, Fischer, & van den Brandt, 2002). Examined the effects of long-term exposure to traffic-related air pollutants on 5,000 adults. Denmark. | Residents near a main road were almost twice as likely to die from heart or lung disease and 1.4 times as likely to die from any cause compared with those who lived in areas with less-traffic. |
| Childhood Cancer. (Pearson, Wachtel, & Ebi, 2000). Associations between traffic density, power lines, and all childhood cancers. Denver. 1979 and 1990. | Children living within 250 yards of streets or highways with 20,000 vehicles per day were six times more likely to develop all types of cancer and eight times more likely to get leukemia. |
| Childhood Cancer. (Knox & Gilman, 1997). Examined 22,458 childhood leukemia or other cancer deaths by where they were born and where they died. England. 1953–1980. | Found a cancer corridor within three miles of highways, airports, power plants, and other major polluters. The greatest danger was a few hundred yards from the highway or pollution facility. |
| Leukemia. (Nordlinder & Jarvholm, 1997). Compared the exposure to gasoline and car exhaust (estimated by the number of cars per area) with the incidence of cancer for persons aged 0–24 years at diagnosis. Sweden. 1975–1985. | Found an association between acute myeloid leukemia and car density. In municipalities with $>$20 cars/km2, the incidence was 5.5 cases per 1 million person-years vs. 3.4 in municipalities with $<$5 cars/km$^2$. |
| Low Birth Weight. (Wilhelm & Ritz, 2003). Examined the relationship of premature birth and low birth weight with traffic using a distance-weighted traffic density measure. Los Angeles. 1994–1996. | An approximately 10–20% increase in the risk of premature birth and low birth weight for infants born to women living near high traffic areas. |
| Asthma Hospitalization. (Edwards, Walters, & Griffiths, 1994). Examined area of residence and traffic flow patterns for children admitted to the hospital for asthma. Birmingham, United Kingdom. | Children admitted with an asthma diagnosis were significantly more likely to live in an area near high traffic flow than were children admitted for nonrespiratory reasons. |
| Childhood Asthma Hospitalization. (Lin, Munsie, Hwang, Fitzgerald, & Cayo, 2002). Examined hospital admission for asthma amongst children ages 0–14, and residential proximity to roads with heavy traffic. Erie County, New York (excluding Buffalo). | Children living in neighborhoods with heavy truck traffic within 200 meters of their homes had increased risks of asthma hospitalization. |

**TABLE 2 (Continued)**

| Health Outcome/Study Description | Findings |
|---|---|
| Asthma Incidences. (Venn, Lewis, Cooper, Hubbard, & Britton, 2001). Examined risk of wheeze in a control sample of 6,147 primary schoolchildren and a random sample of 3,709 secondary schoolchildren. Nottingham, United Kingdom. | Wheezing illness, including asthma, was more likely with increasing proximity of a child's home to main roads. The risk was greatest for children living within 90 meters of the road. |
| Asthma Symptoms. (Duhme, Weiland, Keil, Kraemer, Schmid, Stender, & Chambless, 1996). Investigated the relationship between truck traffic and asthma symptoms among 3,703 students using questionnaires. Munster, Germany. 1994–1995. | Positive associations between both wheezing and allergic rhinitis and truck traffic were found during a 12-month period. |
| Asthma and Respiratory Symptoms. (van Vliet, Knape, de Hartog, Janssen, Harssema, & Brunekreef, 1997). Association of freeway proximity and truck intensity with chronic respiratory symptoms in questionnaires of 1,498 children. South Holland. | Asthma, wheeze, cough, and runny nose were significantly more common in children living within 100 meters of freeways; respiratory symptoms increased near freeway with increasing truck traffic density. |
| Respiratory Symptoms. (Brauer, Hoek, van Vliet, Meliefste, Fischer, Wijga, Koopman, Neijens, Gerritsen, Kerkhof, Heinrich, Bellander, & Brunekreef, 2002). Estimated residential outdoor traffic-related air pollutant concentrations and the development of asthmatic/allergic symptoms and respiratory infections. The Netherlands. | Two-year-old children exposed to higher levels of traffic-related air pollution were more likely to self-report respiratory illnesses (wheezing, ear/nose/throat infections) and physician-diagnosed asthma, flu or serious cold. |
| Lung Function Reduction. (Brunekreef, Janssen, de Hartog, Harssema, Knape, & van Vliet, 1997). Children's lung function and their exposure to traffic-related air pollution using separate traffic counts for automobiles and trucks. The Netherlands. | Exposure to traffic-related air pollution, particularly diesel exhaust particles, may lead to reduced lung function in children living near major motorways. |

the estimated cancer risk from hazardous outdoor air pollutants. Furthermore, race plays an explanatory role in predicting the distribution of this canare risk in the region (Morello-Frosch, Pastor, Porras, & Sadd, 2002; Morello-Frosch, Pastor, & Sadd, 2001).

Some have suggested that researchers, policymakers, and advocates have oversimplified discussions of environmental inequity by narrowly focusing on potential discrimination in regulatory and legal arenas (Cutter & Solecki 1996; Morello-Frosch, 2002; Pulido, 2000). Indeed, research into the disproportionate environmental burden of poor and minority neighborhoods in Southern California and elsewhere has given rise to a theoretical framework that demands a broader understanding of the socioeconomic and political forces that "create 'riskscapes' in which overlapping pollution plumes, emitted by various sources into our air, soil, food, and water pose a range of health risks to diverse communities" (Morello-Frosch, 2002, p. 479). This approach frames the geographic relationships between race, income and the distribution of pollutants in the context of historic socio-spatial processes and the urban political economy in which the environmental inequities arise (Cutter & Solecki 1996; Geronimus, 2000; Morello-Frosch, 2002; Morello-Frosch, Pastor & Sadd, 2001; Pulido, 2000; Pulido, Sidawi, & Vos, 1996). Not only does this approach offer important insight for policymaking by documenting how environmental inequities are distributed across the urban landscape, it also sheds light on the causes and reasons for the persistence of these patterns.

This article embraces this theoretical approach in two ways. First, it expands our understanding of the potential distributional impact of mobile sources of pollution in the region by documenting the magnitude of traffic, particularly for disadvantaged neighborhoods. Although estimates of traffic volume do not provide a direct measure of exposure to pollutants, they have been used as a proxy for pollutant emissions and concentrations in epidemiological studies (Behrentz, et al., in press). Analysis of the distribution of traffic also provides an important precursor to more sophisticated studies of the generation of, dispersion of, and individual exposure to vehicle-related pollutants. For instance, a recent study of the distribution of traffic in California found non-white children were about three to four times more likely to live in areas with high-density traffic than white children, and low-income children had higher potential exposure to vehicle emissions (Gunier, Hertz, Von Behren, & Reynolds, 2003). These results signal that significant inequity may exist in the localized exposure to vehicle-related pollutants. Given the negative health effects associated with such exposure, understanding the distribution of traffic provides important information for public health and siting policy in high-traffic areas even as more direct estimates of individual exposure to pollutants are developed. In fact, the California Legislature recently responded to the health risks of pollution from heavy traffic by passing legislation to protect school children from exposure to hazardous pollutants by mandating that any school site within 500 feet of a freeway, busy traffic corridor, or other source of air toxins be reviewed for potential health risks (S. 352, 2003).

Second, this article embraces a broad theoretical perspective to contextualize the distributional impacts of traffic within the larger historic and structural forces in Southern California. The region's history of discriminatory lending and fragmented land-use development policies provides important insight into the persistence of racial segregation and concentrated poverty. Furthermore, the development of the region's job base and its transportation infrastructure sheds light on the causes for the uneven distribution of traffic and provides important background for policy and planning responses to environmental inequities.

## DATA AND METHODS

The study area represents five counties in Southern California that house over 16 million residents and encompass 34,000 square miles: Los Angeles, Orange, Riverside, Ventura, and San Bernardino Counties. This geographic area is within the planning region of the Southern California Association of Governments, the Metropolitan Planning Organization for six counties in Southern California (including Imperial County) with the responsibility of developing a long-range transportation plan for the region. Four counties in our study area, excluding Ventura County, comprise the South Coast Air Basin administered by the South Coast Air Quality Management District.

The methods used for the present analysis expand the research by Gunier et al. (2003) that found that non-white and low-income children in California were more likely to live in areas with high traffic density. First, we use 2000 demographic and socioeconomic census data to document the distributional impact of traffic, versus that study's use of 1990 data. This distinction is particularly important given the sizeable growth and racial/ethnic change experienced in disadvantaged Southern California neighborhoods in the 1990s (McConville & Ong, 2003; Myers, 2001). We also use more recent 2000 traffic data compared to their use of 1993 data. Second, our analysis incorporates spatial measures of racial segregation, housing, land use, job distribution, and transportation access to provide a broader perspective on the uneven distribution of traffic. Third, whereas Gunier et al. compare the composition of areas with the highest traffic density to that of the general population, our analysis investigates potential traffic disparities across neighborhoods by their minority and poverty status. This approach allows for a more comprehensive perspective on the impact of traffic in disadvantaged neighborhoods, especially because high-poverty and highly segregated areas suffer from numerous challenges including disinvestment, declining property values, deteriorated housing, limited economic opportunity, and poor health that could influence or compound the negative impacts of heavy traffic.

We approximate neighborhoods using census block group boundaries, which are smaller than a census tract and often correspond with features such as major roads, bodies of water, or railroad tracks. In Southern California, census block groups contain on average about 1,500 people and their size can vary depending on land use and population density. We restrict the analysis to block groups with at least 50 persons per square mile.

We categorize areas in the study counties based on their racial/ethnic composition and poverty using 2000 Census data to examine potential disparities in traffic volume by neighborhood type. That is, we aggregate neighborhood measures and traffic volume for block groups in the five-county region into two race-based classifications: Minority and Non-Minority. Likewise, we aggregate our findings into four poverty-based classifications: Very Poor, Poor, Moderate, and Not Poor. We classify areas with over 50% of residents who are Non Hispanic White as Non-Minority Areas and areas with over 50% or more of residents who are not Non Hispanic White as Minority Areas.

We classify block groups with over 40% of residents in poverty as "Very Poor" because these are very low income neighborhoods that often face high unemployment and limited social and economic opportunity. This definition is consistent with research and literature on the urban underclass that defines high-poverty areas as communities with over 40% persons in poverty. Areas with 20 to 40% of residents in poverty are classified as "Poor." This definition is consistent with the Census Bureau that defines poor areas as communities with over 20% of persons in poverty. The Census classifies residents as being in poverty if their total annual family income is below the Federal Poverty Level (FPL), which was $16,700 for a family of four in 1999, the year for which the 2000 Census collected income information. Although adjusted annually for inflation, the FPL is not geographically adjusted. Therefore, in relatively expensive areas such as Southern California, estimates of the poverty level using the FPL likely underestimate the size of the poor population. Still, it provides an established, policy-relevant measure of low socioeconomic status. Because low income and minority neighborhoods may correspond with higher density areas, especially in inner city areas, we also provide summaries of traffic volume for areas based on population density.

Road density and traffic count measures for Southern California are based on line segment data derived from the Highway Performance and Monitoring System maintained by the California Department of Transportation (CalTrans) (California Department of Transportation, 2000). This method most likely underestimates the density of major roads as these data only contain information on roadways for which traffic is monitored and does not provide comprehensive coverage for local roads. Although vehicles are counted continuously by in-road sensors on some major freeways, most roadway counts are performed by electronic counting instruments moved throughout the state in a program of continuous traffic count sampling. Counts are adjusted to an estimate of annual average daily traffic (AADT) based on seasonal fluctuations, weekly variation, and other variables. AADT represents the total volume for the year divided by 365 days.

Using Geographic Information Systems (GIS), we developed estimates of vehicle miles traveled (VMT) for segments of freeways and major roads in the study area. We multiplied the annual average daily traffic (AADT) for each segment by its mileage. To aggregate VMT for each sub-area of the county based on their minority and poverty status, we selected all block groups with a given classification and generated a 200-meter buffer around these areas using GIS. We then summed the total vehicle miles traveled based on the AADT of available road segments and the length of each road segment in miles. We also performed separate VMT summaries for each sub-area based on whether roads were "Freeways" or "Major Roads" according to the jurisdiction flag.

We provide insight into the structural causes and reasons for potential traffic disparities by profiling supplemental measures by neighborhood poverty and minority status (Table 3). We derive racial/ethnic composition, socioeconomic, housing, household vehicle, and commute information from the 2000 Census (Bureau of the Census, 2003a, 2003b). Information on the geographic distribution of existing land use for 2001 and transit service are derived from SCAG (Southern California Association of Governments, 2003). Information on the distribution of residential parcels for 2001 was obtained from the statewide database of the University of California at Berkeley (California Statewide Database, 2003). Employment patterns were obtained from the American Business Information (ABI) database for Los Angeles County for 2000 (American Business Information, 2001). These data contain the number of private sector employees and firms at the block level and were aggregated to the neighborhood boundaries defined by poverty and minority status.

Analysis of residential segregation for racial/ethnic groups and for the poor is conducted at the tract level using the Dissimilarity Index (DI). The DI is the most commonly used measure of segregation. This index indicates the percentage of one group that would have to relocate in order to be evenly distributed with a comparison group in the metropolitan area: the higher the index, the greater the segregation between these groups. The index ranges from *0* to *100*; *0* indicates that no group members would have to move and *100* means that all group members would have to move. The DI is computed using the following equation:

$$Dissimilarity\ Index = \frac{1}{2}\sum_{i=1}^{n}\left[\frac{N_{1i}}{N_1} - \frac{N_{2i}}{N_2}\right]$$

where $N_{1i}$ is the population of a group in *i*th tract, $N_{2i}$ is the population of comparison group in *i*th tract, $N_1$ is the total population of a group in the region, and $N_2$ is the total population of the comparison group in the region. Our DI analysis of segregation for racial/ethnic groups uses Non-Hispanic Whites as the comparison group; our DI for the poor uses the non-poor as the comparison group.

The analysis builds a foundation for future research that is beyond the scope of this article. Although proximity to traffic is a fundamental factor in overall exposure to vehicle-related pollutants, other factors, such as wind direction and the amount of time that individuals spend at home, work, or school in high traffic areas, mediate exposure. Because direct measurement and modeling of individual exposure to air pollution is expensive, analysis of the distribution of urban traffic provides an important context for the conceptualization and planning of future human exposure studies. Multivariate analysis could also provide substantial insight into the neighborhood characteristics associated with high-density traffic. Unfortunately, discrepancies exist between the CalTrans roadway geographic data and the census block group boundaries and limit our ability to use this technique. In the current research, we correct for this discrepancy by buffering neighborhood areas by 200-meters, but multivariate analysis of traffic at the block group level requires substantial data processing to rectify boundaries. Although exposure analysis and multivariate techniques are beyond the scope of this analysis, this article contributes to future research and policy responses by expanding our understanding of the causes, characteristics, and magnitude of traffic, particularly for disadvantaged neighborhoods.

## RESULTS

### Racial Segregation and Concentrated Poverty

Given that vehicle-related pollutants and associated health impacts are concentrated within 150 to 500 meters of major roadways, residential patterns are fundamental to understanding the distributional impacts of traffic and related pollutants because many residents attend school, work, and relax relatively close to home. This section documents the persistence of racial segregation and concentrated poverty in Southern California and discusses how this pattern is the result of complex structural processes including housing discrimination and land-use development policies.

Racial and ethnic distinctions are a primary basis of the spatial separation of residents and play an important role in maintaining inequality among residents (Jaret, Reid, & Adelman, 2003; Logan & Molotch, 1987). Despite the declines in segregation witnessed over the past few decades (Frey & Farley, 1996; Massey & Denton, 1987), African Americans remain the most residentially segregated racial/ethnic group in the nation, followed by Hispanics and Asian and Pacific Islanders (McConville & Ong, 2001). Based on 2000 Census data, the Los Angeles-Long Beach Metropolitan Statistical Area had a Dissimilarity Index score of 67 for African Americans, indicating that 67% of African Americans in that metropolitan area would have to move in order to be evenly distributed among Non-Hispanic Whites in the region (Table 4). Still, the level of segregation of African Americans from Non-Hispanic Whites in the study counties declined

**TABLE 3**

**Neighborhood Characteristics and Data Sources**

| Neighborhood Characteristic | Definition and Data Source |
|---|---|
| **Demographic and Socioeconomic Characteristics:** | |
| Population density | Total persons per square mile. |
| % Non Hispanic White | The percentage of the total population that identified as white and did not indicate they were of Hispanic Origin. |
| % Black/African American | The percentage of the total population identified as Black regardless of Hispanic Origin as well as Black persons who were multiracial. |
| % Latino | The percentage of the total population identified as Whites of Hispanic origin and Others of Hispanic origin. |
| % Asian/Pacific Islander | The percentage of the total population identified as Asian and Native Hawaiian (ANH) or Other Pacific Islanders (PI), regardless of Hispanic Origin, as well as multi-race individuals who indicated they were ANH/PI. |
| % Other | The percentage of the total population identified as Others of Non-Hispanic Origin and American Indians, as well as those who indicated they were two or more races. |
| % Poverty | The percentage of the total population who were in a household income below the federal poverty level. |
| % Less than high school | The percentage of persons 25 years and over whose educational attainment was less than a high school degree or equivalent. |
| % Unemployment | The percentage of the population sixteen years or older who were not employed but were looking for work and were available to start a job. |
| Labor force participation rate | The percentage of the population sixteen years or older who were employed or were actively looking for work. |
| **Residential and Land Use Characteristics:** | |
| % Residential distribution | The percentage of parcels which were residential, by the percentage Single Family Residential and Multifamily Residential (California Statewide Database, 2003). |
| % Housing built before 1960 | The percentage of housing units built before 1960. |
| Average rent | Average rent for renter-occupied housing units. |
| Average home value | Average mortgage for owner-occupied housing units. |
| Land use parity index | The ratio of the percentage of area of an existing land use type in a sub-area to the percentage of area of an existing land use type in the study area. Reported for Transportation, Industrial, and Commercial land use types. |
| **Commute Travel Mode, Transportation Access, and Job Location:** | |
| Work commute mode | The travel mode used to travel for work, broken out by the percentage that use auto, public transportation and other. |

**TABLE 3 (Continued)**

| Neighborhood Characteristic | Definition and Data Source |
|---|---|
| Bus stop parity index | The ratio of the bus stops per square mile in a sub-area to the bus stops per square mile in the study area. Stops represent unique lines for each provider that serves a given intersection. Values over 1 represent areas with a relatively high density of stops. Restricted to Los Angeles County. |
| % Households with a vehicle | The percentage of households that reported a vehicle. |
| Density of jobs and firms | The number of jobs and firms per square mile (American Business Information, 2000). |

*Source.* Bureau of the Census, 2003a, 2003b.

between 1990 and 2000. The level of segregation of Hispanics and Asian and Pacific Islanders, the two fast-growing racial/ethnic groups in Southern California, increased from 1990 to 2000 (McConville & Ong, 2001).

These patterns of racial segregation have given rise to a complex geography of minority neighborhoods in the region, but there are some general patterns. Figure 1 shades neighborhoods in the study counties by the percentage of residents that are minorities. Although some neighborhoods that are predominately minority are in outlying areas, most are located in the densely populated urban core of the region, particularly in areas near downtown Los Angeles and South Los Angeles. The racial and ethnic composition has changed dramatically in poor, minority neighborhoods in the region due largely to immigration of Latinos (McConville & Ong, 2003; Myers, 2001). For instance, the percentage that Latinos comprised of very poor areas increased threefold between 1970 and 2000, while the percentage of blacks within these areas declined (McConville & Ong, 2003).

The persistence of residential segregation stems in part from historic discrimination by financial and real estate institutions (Massey & Denton, 1993). Exclusionary zoning practices and covenants denied minorities the right to reside or own property in certain neighborhoods. Redlining practices and discriminatory mortgage discouraged the infusion of credit and financial resources into minority areas until the 1960s (Morello-Frosch,

**TABLE 4**

**Segregation of Minority Groups from Non-Hispanic Whites, Dissimilarity Index, 2000**

| | Segregation (DI) from Non-Hispanic White | | | | Segregation (DI) from Non-Poor Residents |
|---|---|---|---|---|---|
| Metropolitan Statistical Area | Black/African American | Latino | Asian/Pacific Islander | Minority | Poor |
| Southern California | 63 | 59 | 47 | 52 | 77 |
| Los Angeles-Long Beach | 67 | 63 | 48 | 56 | 73 |
| Orange County | 37 | 55 | 40 | 45 | 84 |
| Riverside-San Bernardino | 45 | 43 | 37 | 39 | 77 |
| Ventura | 47 | 56 | 29 | 49 | 86 |

*Source.* Derived using data from Bureau of the Census, 2000a, 2000b.

2002; Pulido, 2000; Pulido, Sidawi, & Vos, 1996). Despite the dismantling of many of these discriminatory policies, housing discrimination continues in the nation's metropolitan areas. The Housing Discrimination Project, sponsored by the Department of Housing and Urban Development, investigated housing discrimination in 23 metropolitan areas in the second half of 2000 using a paired test. They had two individuals, one minority and the other white, pose as otherwise identical homeseekers and visit real estate or rental agents to inquire about advertised housing units. Results indicate that, although the incidence of discrimination has declined since the previous study in 1989, housing discrimination persists for African Americans, Hispanics and Asian and Pacific Islanders in both rental and sales markets (Turner & Ross, 2003; Turner, Ross, George, Yinger, 2002).

Patterns of racial segregation are closely intertwined with the persistence of concentrated poverty in Southern California. Nationwide, the concentration of urban poor in high poverty areas increased from 1970 to 1990 (Jargowsky, 1997). Analysis of 2000 Census data revealed the concentration of poverty decreased in most metropolitan areas (Jargowsky, 2003). Despite this national trend, poor residents and, more specifically, poor minority residents in the Los Angeles-Long Beach Metropolitan Statistical Area became increasingly concentrated in poor neighborhoods (Jargowsky, 2003; McConville & Ong, 2003). A separate measure confirms that the poor are highly segregated from the non-poor in Southern California. Between 73 and 86% of poor residents would have to relocate within the region in order to be evenly distributed among the non-poor in the region (Table 4).

The entrenchment of residential segregation for the poor and minorities in Southern California raises serious equity concerns given that high-poverty and minority neighborhoods are plagued by disinvestment, declining property values, deteriorated housing, limited business opportunities, insurance redlining, and poor schools (Jaret, Reid, & Adelman, 2003; Ong, 2002; Pettit, Kingsley, & Coulton, 2003; Squires, 2003). Such patterns are not merely the result of market forces that geographically sort residents by their ability to pay for housing and services, but are the result of complex structural and

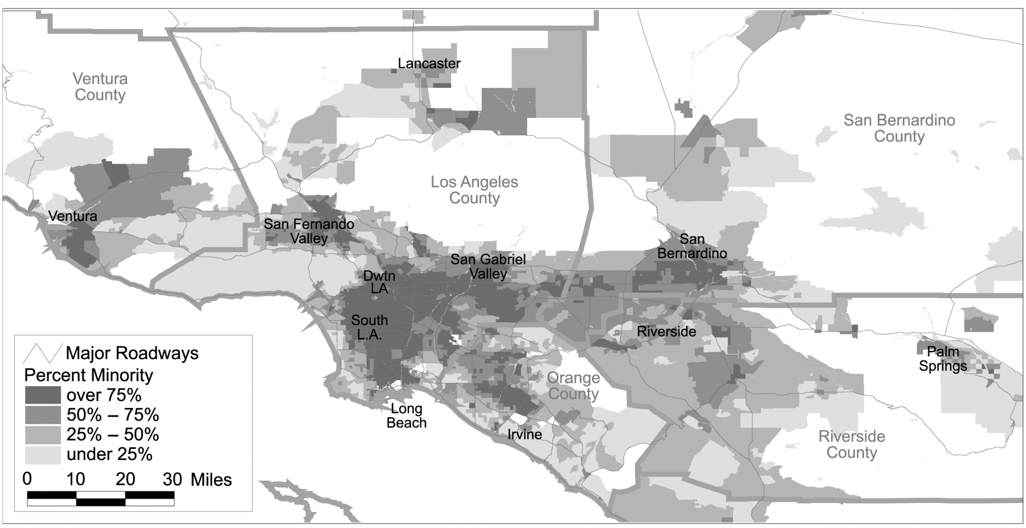


**FIGURE 1**

**Minority Neighborhoods, Southern California, 2000**

economic processes and social relations (Morrello-Frosch, 2002; Pulido, 2000; Wilson, 1987). These processes have resulted in neighborhoods with high concentrations of residents with limited education, job experience, and opportunity for relocation (Massey & Denton, 1993; Wilson, 1987). Over 39% of residents age 25 or older in Minority and Poor areas have less than a high school education compared to less than 13% in Non-Minority and Non-Poor areas (Table 5). Because a high school diploma is often required for entry-level jobs, it is not surprising these areas also have lower rates of labor force participation. The percentage of adults who were employed or looking for work was approximately 13% lower in Minority areas than in Non-Minority areas and 22% lower in the poorest areas compared to the least poor. Among those in the labor force, those residing in minority and poor neighborhoods have the highest rates of unemployment, especially in Very Poor neighborhoods.

Patterns of racial segregation and concentrated poverty have a strong geographic overlap in Southern California (Figure 2). While some Minority areas are not poor, when aggregated together minority neighborhoods have a poverty rate over 20%, our classification of Poor areas (Table 5). Likewise, although some Poor areas are non-minority, approximately 84% of residents of Poor areas and 92% of residents in Very Poor areas are minority.

Because minority and poor neighborhoods have a higher population density than the remainder of the region (Table 5), it is not surprising that these areas also have a higher prevalence of multifamily residential parcels and older buildings (Table 6). Furthermore, these areas have a much higher concentration of transportation, industrial, and commercial existing land use. These patterns are significant to discussions of environmental equity as recent research suggests these land use types play an explanatory role in the level of estimated cancer risk from mobile and stationary source emissions (Morello-Frosch, Pastor, Porras, & Sadd, 2002; Morello-Frosch, Pastor, & Sadd, 2001).

Pulido (2000) provides a historical overview of residential and land use patterns in the Los Angeles region to show how the central areas of Los Angeles, which were once

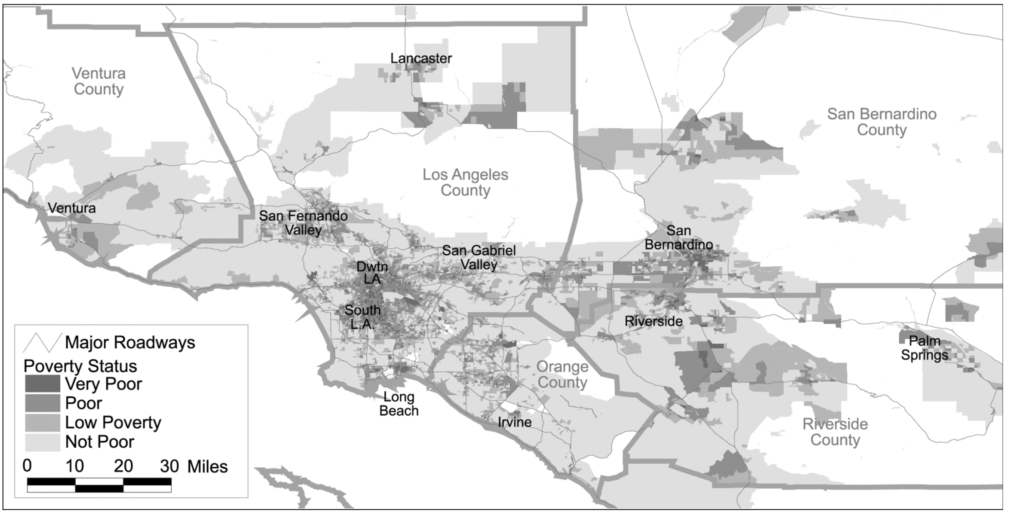


**FIGURE 2**

**High Poverty Areas, Southern California, 2000**

**TABLE 5**

**Demographic and Socio-Economic Characteristics by Minority and Poverty Status, 2000**

| | Race/Ethnicity | | Poverty Status | | | |
|---|---|---|---|---|---|---|
| | Minority Area | Non-Minority Area | Very Poor | Poor | Low Poverty | Not Poor |
| Population density: | 3,667 | 1,171 | 2,508 | 2,850 | 1,719 | 1,492 |
| Race/ethnicity: | | | | | | |
| % Non Hispanic White | 19 | 71 | 8 | 16 | 35 | 59 |
| % Black/African American | 11 | 3 | 16 | 11 | 8 | 5 |
| % Latino | 55 | 14 | 66 | 61 | 43 | 21 |
| % Asian/Pacific Islander | 13 | 9 | 7 | 9 | 12 | 13 |
| % Other | 3 | 3 | 2 | 3 | 3 | 2 |
| Socio-economic characteristics: | | | | | | |
| % Poverty | 21 | 7 | 48 | 28 | 15 | 5 |
| % Less than high school | 39 | 10 | 61 | 48 | 29 | 13 |
| % Unemployment | 9 | 5 | 17 | 11 | 8 | 5 |
| Labor force participation rate | 68 | 81 | 58 | 65 | 73 | 80 |

*Source.* Derived using data from the Bureau of the Census, 2000 Census, PL, and SF3.

industrial suburbs for working-class whites, have become part of the minority and poor inner city, in part due to industrial and suburban development outside the urban core. She notes that "because of the poverty of central Los Angeles and its land use fragmentation and poor services, few large, well-financed firms in growth sectors move there" (p. 32). Rather, small polluting industries and large-scale hazards are drawn to impoverished central areas. She suggests that newer suburban communities "do not have the same concentration of hazardous industrial activities, and enjoy more effective zoning and land-use regulations" than poor and minority inner city areas that often suffer from conflicting land use that intensify environmental hazards (p. 32). For instance, ineffective

**TABLE 6**

**Residential and Land Use Characteristics by Minority and Poverty Status, 2000**

| | Race/Ethnicity | | | Poverty Status | | |
|---|---|---|---|---|---|---|
| | Minority Area | Non-Minority Area | Very Poor | Poor | Low Poverty | Not Poor |
| Residential distribution[a]: | | | | | | |
| % Residential | 82 | 78 | 76 | 79 | 77 | 83 |
| % Single family residential | 82 | 92 | 52 | 68 | 84 | 95 |
| % Multifamily residential | 18 | 8 | 48 | 32 | 16 | 5 |
| Age of housing: | | | | | | |
| % Housing built before 1960 | 41 | 28 | 48 | 42 | 37 | 29 |
| Housing costs: | | | | | | |
| Average rent | 700 | 990 | 550 | 660 | 800 | 1,030 |
| Average home value | 177,370 | 317,900 | 135,960 | 145,040 | 184,820 | 306,250 |
| Land use parity index[b]: | | | | | | |
| Transportation land use | 1.5 | 0.8 | 2.0 | 1.6 | 1.1 | 0.9 |
| Industrial land use | 2.1 | 0.5 | 2.3 | 1.8 | 1.1 | 0.8 |
| Commercial land use | 1.8 | 0.7 | 2.5 | 2.1 | 1.5 | 0.9 |

*Notes.* Except as noted, results are derived using data from Bureau of the Census, 2000a, 2000b.
[a]Residential Distribution results are based on parcel tax assessor information from the California Statewide Database, 2000.
[b]Values over one represent areas with a relatively higher percentage of the designated existing land use types.

zoning practices have resulted in the presence of older, single family homes between or adjacent to large commercial or industrial buildings. Furthermore, because minorities were historically excluded from new suburbs that tended to be primarily zoned for single-family residential units, Pullido asserts that minorities became concentrated in the multi-family units in the barrio and ghetto. These residential and land use patterns and ineffective zoning practices could have significant implications for the exposure to vehicle-related pollutants in poor and minority neighborhoods especially if residents reside, work, or attend school near transportation, industrial, and commercial land uses that generate significant levels of traffic.

## Job Centers and the Transportation Network

The development of Southern California's job base and transportation infrastructure that occurred in conjunction with the residential and land use development practices discussed above provides important context for understanding the uneven distribution of traffic in the region. This section discusses the job distribution, transportation access and road density of neighborhoods by minority and poverty status.

The distribution of jobs in Southern California in many ways mirrored the patterns of industrial development in which larger, well-financed firms with jobs geared towards highly educated and skilled workers tended to locate in proximity to outer suburbs, whereas smaller firms requiring less education and fewer skills tended to have a higher presence more centrally, in closer proximity to inner city areas. Still, many disadvantaged neighborhoods in Southern California are job centers (Figure 3). Minority and Poor areas have a higher density of jobs and firms than the rest of the region (Table 7).

The development of the massive freeway system in the region in the late 1950s and 1960s helped facilitate the relocation of middle and upper class people to the outer suburbs, concentrating poorer, largely minority populations in the industrial center. The massive freeway system was constructed through a number of inner-city minority neighborhoods and promoted further fragmentation of neighborhood institutions and communities (Geronimus, 2000; Morello-Frosch, 2002; Pulido, 2000; Romo, 1983). The development of the transportation infrastructure and distribution of roadways is directly related to the potential disparities in traffic patterns. Considering that poor and minority neighbors tend to have higher population densities and be centrally located near job centers, we are not surprised that roadway density is highest in these areas (Figure 4). In our study area, the road density of high poverty areas is almost two times that of the least poor neighborhoods (Table 8). Areas of high population density have six times the road density compared to areas of low population density in Southern California.

Despite the higher concentration of roadways in their neighborhoods, residents of disadvantaged areas have fewer transportation resources. Whereas approximately 95% of households in Minority areas have a household vehicle, only 86% in Minority areas had a vehicle (Table 9). Eighty-one percent or fewer had access to a vehicle in Poor and Very Poor areas compared to 96% in Non-Poor areas. Furthermore, a lower percentage of workers traveled to work by auto in disadvantaged neighborhoods while a higher percentage traveled by public transportation. These patterns may reflect that workers living in Non-Poor areas tend to travel by auto because they travel further for work, are better able to shoulder the financial burden of car ownership, or may have lower access to public transportation.

The transportation infrastructure of Southern California is a vital component of the region's economic health. It provides the mobility essential for economic activities and

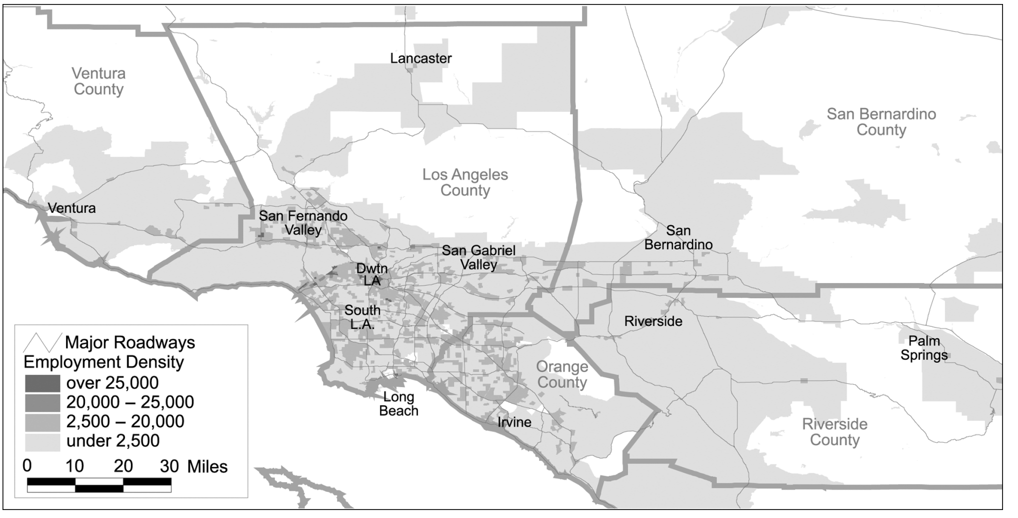


**FIGURE 3**

**Employment Density, Southern California, 2000**

goods movement, as well as a mechanism for personal and work-related travel. Despite these benefits, the geographic patterns of the transportation system raise equity concerns in light of our growing knowledge that the health costs of vehicle-related pollutants may be highly localized. Although the above results regarding the differences in roadway density and transportation access across neighborhood types are insufficient to fully assess the costs and benefits of urban roadways to residents of disadvantaged areas, the patterns point to the need for additional empirical research to further investigate the causes and reasons for potential traffic disparities.

**TABLE 7**

**Job, Firm and Population Density, by Neighborhood, 2000**

| | Density of Jobs (Jobs Per Square Mile) | Density of Firms (Firms Per Square Mile) | Population Density (Persons Per Square Mile) |
|---|---|---|---|
| Poverty status: | | | |
| Very Poor | 1,174 | 156 | 2,508 |
| Poor | 1,384 | 173 | 2,850 |
| Low Poverty | 952 | 121 | 1,719 |
| Not Poor | 675 | 88 | 1,492 |
| Race/ethnicity: | | | |
| Minority Area | 1,439 | 177 | 3,667 |
| Non-Minority Area | 577 | 78 | 1,171 |
| Population density: | | | |
| Very High | 5,084 | 722 | 9,877 |
| High | 2,868 | 396 | 4,595 |
| Medium | 2,225 | 282 | 3,114 |
| Low | 352 | 40 | 617 |

*Source*. Derived using establishment and employment counts from American Business Information, 2001 and Bureau of the Census, 2000a.

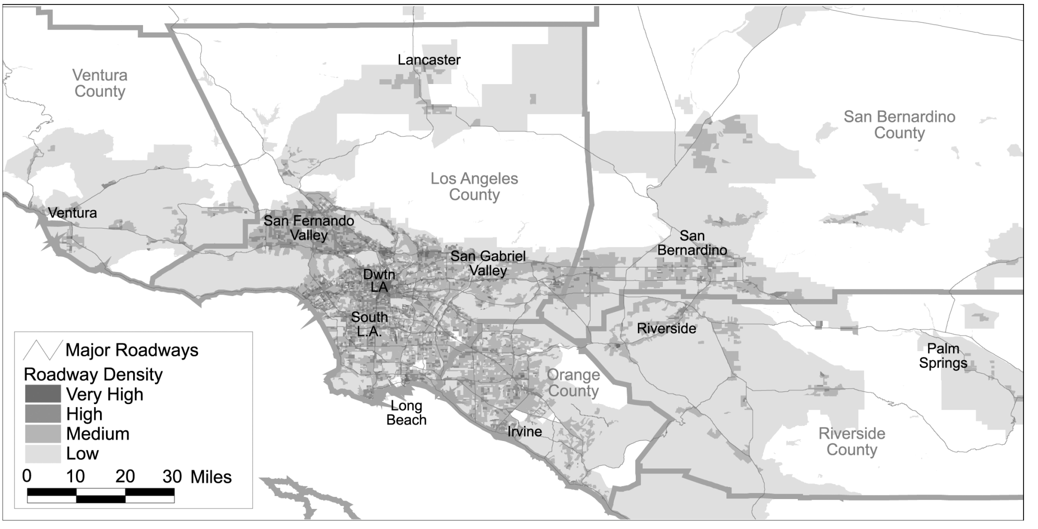


**FIGURE 4**

**Roadway Density, Southern California, 2000**

## Traffic Density in Minority and High-Poverty Neighborhoods

Patterns of urban travel and traffic have risen from these structural processes of residential fragmentation, uneven land use development, and the construction of the transportation infrastructure. Given the high density of roads, residents, and jobs in minority and high-poverty neighborhoods, these areas should have higher levels of aggregate traffic than the rest of the region. This is consistent with previous findings that traffic levels are disproportionately higher in the central part of the city of Los Angeles (Ong &

**TABLE 8**

**Road Density by Neighborhood, 2000**

| | | Road Density by Type | |
|---|---|---|---|
| | Road Density | Freeway | Major Road |
| Poverty status: | | | |
| Very Poor | 5.34 | 0.65 | 4.69 |
| Poor | 5.23 | 0.67 | 4.56 |
| Low Poverty | 4.04 | 0.52 | 3.53 |
| Not Poor | 2.55 | 0.35 | 2.19 |
| Race/ethnicity: | | | |
| Minority Area | 3.84 | 0.47 | 3.37 |
| Non-Minority Area | 2.03 | 0.30 | 1.73 |
| Population density: | | | |
| Very High | 11.84 | 0.90 | 10.94 |
| High | 10.85 | 0.99 | 9.86 |
| Medium | 8.79 | 0.92 | 7.87 |
| Low | 1.91 | 0.32 | 1.58 |

*Source.* Derived from California Department of Transportation, 2000.

**TABLE 9**

**Commute Travel Mode and Transportation Access by Minority and Poverty Status, 2000**

| | Race/Ethnicity | | Poverty Status | | | |
|---|---|---|---|---|---|---|
| | Minority Area | Non-Minority Area | Very Poor | Poor | Low Poverty | Not Poor |
| Work commute mode: | | | | | | |
| % Auto | 86 | 91 | 66 | 81 | 89 | 92 |
| % Public transportation | 7 | 2 | 20 | 10 | 4 | 2 |
| % Other | 5 | 5 | 12 | 6 | 4 | 2 |
| Transportation access: | | | | | | |
| Bus stop parity index[a] | 1.7 | 0.6 | 4.7 | 2.3 | 1.5 | 0.7 |
| % Households with a vehicle | 86 | 95 | 66 | 81 | 91 | 96 |

[a]Values over one represent areas with a relatively high level of transit service.

Sung, 2003). This section documents the magnitude of traffic for these neighborhoods in Southern California and suggests the extent to which disadvantaged areas may experience disparate exposure to vehicle-related pollutants.

We find high-poverty areas in Southern California have almost twice the traffic density of the least poor areas (Table 10). Minority areas have almost 2.5 times the traffic density of Non-Minority areas. This suggests residents of Minority and Poor areas, as expected, reside in close proximity to high levels of traffic and are, by association, at higher risk of exposure to vehicle-related pollutants. Very poor areas, which represent the most disadvantaged areas in the region, had a significantly higher traffic density than Minority or Poor areas, perhaps because these areas have the highest roadway density. Minority neighborhoods cover a large portion of Southern California and include very poor areas. Given the magnitude of the disparities in the distribution of traffic within these neighborhoods, there is reason to suspect that residents of minority and poor

**TABLE 10**

**Distribution of Traffic Density & AADT by Neighborhood Type, 2000**

| | | | VMT By Road Type | |
|---|---|---|---|---|
| | Traffic Density (AADT * Mi/SqM) | VMT (AADT * Mi) | Percentage of VMT on Freeways | Percentage of VMT on Major Roads |
| Poverty status: | | | | |
| Very Poor | 102,000 | 35,260,400 | 53 | 47 |
| Poor | 93,100 | 134,891,700 | 54 | 46 |
| Low Poverty | 70,300 | 173,806,000 | 53 | 47 |
| Not Poor | 52,900 | 246,517,300 | 56 | 44 |
| Race/ethnicity: | | | | |
| Minority Area | 89,100 | 244,366,800 | 56 | 44 |
| Non-Minority Area | 36,900 | 193,614,500 | 55 | 45 |
| Population density: | | | | |
| Very High | 181,700 | 89,274,500 | 44 | 56 |
| High | 156,600 | 130,984,300 | 49 | 51 |
| Medium | 137,200 | 154,795,200 | 53 | 47 |
| Low | 37,700 | 243,775,400 | 62 | 38 |

neighborhoods are at a higher risk of the health effects associated with vehicle-related pollutants such as respiratory illnesses, adverse birth outcomes, cancer, and mortality (Oosterlee, Drijver, Lebret, Brunekreef, 1996; Pearson, Wachtel, & Ebi, 2000; Savitz & Feingold, 1989; van Vliet, et al., 1997; Wilhelm & Ritz, 2003).

We also investigate how the level of traffic (VMT) is distributed across freeways and major roads in these neighborhoods. We find almost half (44 to 47%) of VMT in these areas is on major roads as compared to freeways (Table 5). This finding indicates the adverse effects of traffic density are spread across the urban roadway system and not confined to freeways. The distinction of traffic levels between major roads and freeways is even more pronounced for high-density areas. While less than 40% of VMT is on major roads in the lowest density areas, 56% of VMT is on major roads in areas of the region's highest density. Clearly, non-freeway arterials play a major role in sub-regional traffic patterns and should be included in future research and policy responses.

Our result that minority and high-poverty areas have higher traffic densities provides an important indicator that residents in poor, minority, and high-density neighborhoods are potentially exposed to higher pollution levels from mobile sources. Residential proximity to traffic is a fundamental factor in overall human exposure to vehicle-related air pollutants, but other factors mediate exposure. Pollutant dispersion varies by meteorological conditions, such as the direction and speed of prevailing winds. Furthermore, personal exposure to vehicle-related air pollutants is directly related to individual time-activity and travel patterns. Our findings that high-poverty and minority areas bear a disproportionate amount of traffic reiterates the need for more individual- and neighborhood-level exposure studies to determine the severity of exposures after accounting for time-activity patterns.

Our findings also raise concerns that residents of high-poverty and minority areas may experience higher exposure to vehicle-related pollutants, not only outdoors but also indoors. The housing stock in these neighborhoods tends to be older and more multifamily, characteristics associated with higher air exchange rates (Colome, Wilson, & Tian, 1994). That is, outdoor air mixes with indoor air at a greater rate in these buildings. Therefore, residents of these buildings are likely to be exposed to greater levels of vehicle-related pollutants from outdoor sources. Over 40% of households in Poor and Minority areas reported their buildings were built prior to 1960, compared to less than 30% in Non-Minority and Non-Poor areas (Table 6). Whereas only 18% of residential parcels in Minority areas were multifamily, 32% were multifamily in Poor areas and 48% were multifamily in Very Poor areas. This pattern suggests if residents spend equal amounts of time indoors across neighborhood types, that residents in poor and minority neighborhoods would likely be exposed to higher levels of vehicle-related pollutants due to greater penetration of outdoor air, even for comparable traffic densities.

## DISCUSSION

The growing evidence of the negative health effects of vehicle-related pollutants immediately adjacent to heavily traveled roadways suggest the cost of living, working, or attending school in these areas may be much higher than previously understood. Our finding that minority and high-poverty neighborhoods bear over twice the level of traffic density is consistent with previous research and suggests that those who spend time in these areas are potentially exposed to localized concentrations of vehicle-related pollutants associated with chronic illness, lung impairment, and increased morbidity and mortality.

This pattern raises a host of equity concerns especially in light of persistent patterns of racial segregation, concentrated poverty, and fragmented land-use development. For instance, it may not be surprising that poor and minority areas have a higher density of major roads and traffic given that these areas have a higher population density than the rest of the region. An equity question that arises from this pattern, though, is whether residents of poor and minority areas benefit from these roadways at a level proportional to the health burden they bear. If residents do not travel on the roadways that pass through their neighborhood at the same rate as non-residents, an inequity may exist. That is, if most of the trips underlying the higher traffic density in these areas are from non-residents commuting to local job centers, residents of disadvantaged areas may not benefit from roadways at the same rate as non-residents. In fact, they may suffer substantial health costs related to non-resident trips while commuters return every evening to less-polluted residential areas.

Of course, this scenario is a rather simplistic version of the complicated environmental equity questions raised by our findings. Still, our descriptive results suggest it may warrant further investigation. For instance, we show that residents of minority and poor areas are less likely to have a household vehicle and are less likely to commute to work in an auto. Furthermore, disadvantaged areas have much higher levels of public transit service and employed residents of these areas are more likely to commute using public transit than workers in the rest of the region. Transit buses are responsible for a relatively small portion of overall vehicle-related emissions in California. Heavy-duty gas and diesel buses account for less than 5% of on-road nitrogen dioxide emissions and less than 2% of reactive organic gas (California Air Resources Board, 2003b). Over 80% of the bus fleet of the Los Angeles County Metropolitan Authority, the largest transit provider in Southern California, operates using compressed natural gas (Los Angeles County Metropolitan Authority, 2003). These patterns by no means answer the larger equity question but support the hypothesis that residents of disadvantaged areas may not use roadways or be responsible for the same level of vehicle-related pollutants in their neighborhood at the same rate as non-residents.

Future research could address this issue by analyzing travel patterns by residential neighborhood type. While aggregate commute patterns can be investigated using available census data and household travel surveys, such research will be complicated by the difficulty and expense of tracking or estimating the routes used for individual trip segments. Such analysis is further complicated by the fact that major roadways carry a substantial amount of non-residential traffic. In fact, heavy duty diesel trucks used for commercial goods movement are responsible for a substantial portion of daily trips in Southern California and about 70% of the estimated carcinogenic risk from air toxins due to diesel particulate emissions (South Coast Air Quality Management District, 1999; Southern California Association of Governments, 2004). For instance, the segment of the 710 freeway that passes from the Ports of Long Beach and Los Angeles through the low-income, minority communities of Lynwood, South Gate, and Bell into East Los Angeles, carries over 32,000 trucks per day, comprising up to 15% of the overall traffic on this segment (California Department of Transportation, 2002). Much of this truck traffic carries goods throughout the region. Although this segment of the 710 freeway is one of the heaviest truck corridors in Southern California, this pattern reiterates the analytical challenge of understanding the extent to which residents or non-residents trips are responsible for the traffic and associated air pollution in disadvantaged neighborhoods.

Even if future work demonstrates that non-residents are responsible for the majority of trips on roadways in minority and poor areas, this would not fully address the equity question raised by our finding that disadvantaged areas bear over twice the level of traffic density. Even if residents do not use major roadways at the same rate as non-residents, the high density of roads could benefit residents in other ways. For instance, the transportation infrastructure in these areas could be partially responsible for the presence of local job centers and may indirectly benefit residents by enhancing nearby employment opportunities. Furthermore, many residents of poor and minority areas in Southern California travel a substantial distance from their residence for work. Even if these trips do not comprise a majority of trips on nearby roadways, the ease of travel offered by the high density of near-by roadways may provide a vital resource. In cases where high traffic density or close proximity to a major roadway suppress property values, living near a major roadway or freeway may offer low-income families more affordable housing options.

Of course there are no easy answers to this question because the benefits and costs of the transportation infrastructure vary across communities and individuals and are difficult to quantify. Still, our results and other emerging research demonstrates that it is important for research, policy, and planning to respond to our growing understanding of the localized negative health effects of vehicle-related pollutants and potential neighborhood disparities of exposure.

Advances in the fields of environmental health, atmospheric science, and epidemiology are needed to inform policy and planning responses to the environmental hazards of vehicle-related pollutants. The California Legislature's recent action to restrict the siting of schools within 500 feet from a freeway or busy traffic corridor is a significant response to the growing body of research in these fields (S. 352, 2003). This includes the recent study by Zhu et al. (2002) documenting that vehicle-related pollutants are concentrated within 150 to 500 meters of major roadways. Mandates against siting public facilities for vulnerable populations in high-traffic areas may remain an important strategy to promote public health, but this response may not be realistic or politically feasible in urban areas with serious levels of overcrowding. Furthermore, this solution alone does not address the exposure of children attending existing schools. The Legislature acknowledged this by authorizing corrective measures to mitigate air quality problems in schools in close proximity to major roadways (S. 352, 2003).

The policy response to the siting of schools near major roadways raises questions regarding the appropriate response to mitigate exposure experienced within residential, employment, commercial, and recreational land uses in high-traffic areas. Widespread relocation of residents from these areas seems highly unlikely and, given pressures of overcrowding and population growth, a ban on a wide range of land uses near major roadways may not be realistic. Further scientific insight is needed to help policy makers, planners, and public health officials strategize an appropriate response. For instance, we know from a recent study that pollutant concentrations between a downwind location and an upwind location at similar distances from a freeway can differ by an order of magnitude (Zhu, Hinds, Kim, & Sioutas, 2002). These results suggest the need to develop a better understanding of how vehicle-related pollutants disperse immediately adjacent to major roadways and to assess how successful potential solutions such as barriers, sound walls, or land-use buffers are in mediating the concentration of pollutants and associated exposures.

Responses should also recognize that people spend most of their time indoors or in vehicles (Klepeis, et al., 2001) where pollutant concentrations can be significantly different than those outdoors. Indoor pollutant concentrations due to penetration of outdoor air are influenced by residential air exchange rate, house volume, and pollutant decay rate, while pollutant concentrations in a vehicle are related to the other vehicles it follows, its own exhaust, and surrounding traffic densities (Behrentz, et al., in press; Rodes, et al., 1998). These factors are important for understanding the magnitude of the health risk of vehicle-related pollutants near major roadways and for developing appropriate policy responses and strategies to mitigate in-vehicle and indoor exposures in high-traffic areas. Direct measurement of personal exposure is an important tool in understanding the conditions and magnitude of exposure (Paustenbach, 2000), but unfortunately it is expensive and limited in the number of subjects that can be studied. Using the patterns uncovered through direct measurement and related studies, ongoing human exposure research is developing techniques to model individual- and neighborhood-level exposure to vehicle-related pollutants and other air pollutants based on time-activity and travel patterns (Wu, Lurmann, Winer, Lu, & Turco, in press). Because of the limited scope of direct measurement, these models of human exposure will help quantify the potential exposures to vehicle-related pollutants after taking into consideration the amount of time that residents spend at home, traveling, or at work or school.

Our finding that minority and poor neighborhoods have a higher prevalence of older and multifamily buildings illustrates a convergence between exposure studies, potential inequities, and the structural processes discussed in this article. The fact that exposure studies indicate these building types tend to have higher rates of indoor penetration of outdoor pollutants suggests that residents of disadvantaged areas may experience greater levels of indoor exposure to vehicle-related pollutants. This pattern, coupled with our finding that these areas bear over twice the level of traffic, suggests the physical and built environment of poor and minority neighborhoods, which is the result of processes of racial segregation, restrictive covenants, and the construction of the transportation infrastructure, has played a significant role in potential disparate exposures.

These linkages reiterate the need to understand that the disparate traffic levels experienced by poor and minority neighborhoods are embedded in a larger historic and structural context of fragmented development and represent a significant environmental inequity with potentially serious health implications for disadvantaged neighborhoods. This pattern is compounded by the fact these areas suffer from numerous health disparities, including higher rates of asthma prevalence, hospitalization, and mortality, as well as close proximity to other environmental hazards.

The regional-scale conformity process has benefited the region by promoting healthful air quality within Southern California, but current practices may be insufficient to detect and address the implications of the potentially high concentration of vehicle-related pollutants in high-traffic areas. Currently, regional air quality and transportation planning policies primarily consider the costs and implications of travel and associated pollutants on regional population health, economic activities, and ambient air quality (South Coast Air Quality Management District, 2003; Southern California Association of Governments, 2004). SCAQMD and SCAG have embraced federal mandates to address environmental justice concerns in air quality and transportation planning processes by explicitly addressing demographic and socioeconomic impacts in their regional plans. Given that many health impacts of traffic are heightened within 150 to 500 meters of roadways, environmental justice planning and research must refine the scale of analysis and mitigation to account for these localized health implications. Regional or even neighborhood measures could potentially mask patterns immediately adjacent to major roadways and preclude a more localized understanding of the health impacts of vehicle-related air pollution. Also, our findings suggest it is important to consider impacts near freeways and major roadways as both carry significant levels of traffic.

Policy, planning, and public health responses to the environmental hazards of high-density traffic should be multifaceted and pursue many avenues simultaneously. These efforts should be grounded in environmental health and atmospheric science in order to identify land use types that lower overall human exposure adjacent to major roadways and ways that the built urban environment can be structured to mitigate the dispersion of dangerous pollutants. Plans for new developments can integrate barriers such as sound walls or buffers to lessen the concentration of vehicle-related pollutants. Furthermore, planners may consider development patterns that integrate land use types to reduce vehicle trips between home and activities such as work, school, or recreational activities. Mixed-use development, though, requires careful evaluation to avoid high cumulative air pollution concentrations from multiple commercial, industrial, or transportation land use.

Although responses to the negative effects of high-density traffic in built-out urban areas can be based on similar principles, redevelopment and mitigation efforts in these areas will face numerous logistical challenges. State and regional agencies and local municipalities should consider implementing appropriate traffic reduction or physical mitigation measures within high-traffic corridors that represent the greatest danger to public health. Furthermore, local land use decision-making processes should consider roadways with dangerously high vehicle-related pollutants as incompatible with sensitive land use such as schools, hospitals, or homes (California Environmental Protection Agency and California Air Resources Board, 2004). The environmental review process for major transportation expansions should consider ways to address the health impacts of vehicle-related pollutants immediately adjacent to the project.

Although siting, land use decisions, and traffic mitigation efforts at the local level will be a critical part of the planning and public health response to the localized health effects of traffic, regional coordination is needed to ensure a coordinated response across Southern California. This is important in order to avoid a fragmented approach that fails to address the needs of disadvantaged communities that often suffer from less effective zoning and land-use regulation. Given the traffic and health disparities faced by residents of disadvantaged areas, solutions should be tailored to the structural, land use, and geographic patterns of poor and minority communities, especially because many solutions devised for these areas will be applicable in other parts of the region.

## CONCLUSION

Historic and structural processes including racial segregation, concentrated poverty, uneven land use development, and the construction of the transportation system played an important role in current traffic disparities within Southern California. In aggregate, minority and poor neighborhoods have a higher population density, lower housing values, and a higher density of freeways and major roads. In many cases, these areas are job centers even though residents tend to have lower levels of educational attainment and less of a connection with the labor market. These neighborhoods bear over two times the level of traffic density compared to rest of the region. Furthermore, they have older and more multifamily housing, which is associated with higher rates of indoor exposure to outdoor pollutants.

We have just begun to understand the public heath, policy, and societal implications of the localized dispersion of vehicle-related pollutants on the health of metropolitan neighborhoods. This article contributes to this discussion by documenting the magnitude of traffic across neighborhood types and provides important background for policy and planning responses to environmental inequities by contextualizing traffic disparities within the larger urban structure in which they arise.

**ACKNOWLEDGEMENT:** The authors wish to thank all those who provided helpful suggestions for this article and related research, including the anonymous reviewers for the *Journal of Urban Affairs*. We also thank Fred Lurmann and Tami Funk at Sonoma Technology, Inc. for providing Caltrans traffic count data. Support for this project was provided by the Ralph and Goldy Lewis Center for Regional Policy Studies of the University of California, Los Angeles, by the UCLA Institute of the Environment, and by the Southern California Particle Center and Supersite, which received funding from the U.S. Environmental Protection Agency (Grant R82735201) and the California Air Resources Board (Contract 98–316).

## REFERENCES

American Business Inventory. (2001). *2000 establishment and employment block group counts*. Omaha, NE: infoUSA.

American Lung Association. (2002). *Annotated bibliography of recent studies on the health effects of air pollution*. Available: http://www.lungusa.org/air/air_specialrpt_index.html [April 2004].

Asthma and Allergy Foundation of America. (1998). *For life without limits*. Available: http://www.aafa.org/states/sttab1.cfm [March 2004].

Behrentz, E., Fitz, D. R., Pankratz, D., Sabin, L., Colome, S. D., Fruin, S., & Winer, A. M. (in press). Measuring self-pollution in school buses using a tracer gas technique. *Atmospheric Environment*.

Boer, J. T., Pastor, M. Jr., Sadd, J. L., & Snyder, L. D. (1997). Is there environmental racism? The demographics of hazardous waste in Los Angeles County. *Social Science Quarterly*, *78*(4), 793–810.

Brauer, M., Hoek, G., Van Vliet, P., Meliefste, K., Fischer, P. H., Wijga, A., Koopman, L. P., Neijens, H. J., Gerritsen, J., Kerkhof, M., Heinrich, J., Bellander, T., & Brunekreef, B. (2002). Air pollution from traffic and the development of respiratory infections and asthmatic and allergic symptoms in children. *American Journal of Respiratory and Critical Care Medicine*, *166*(8), 1092–1098.

Brunekreef, B., Janssen, A. H., de Hartog, J., Harssema, H., Knape, M., & van Vliet, P. (1997). Air pollution from truck traffic and lung function in children living near motorways. *Epidemiology*, *8*, 298–303.

Bureau of the Census. (2003a). *Census 2000, summary file 3*. Available: http://www.census.gov/main/www/cen2000.html [August 2004].

Bureau of the Census. (2003b). *Census 2000, Redistricting data (P.L. 94–171)*. Available: http://www.census.gov/main/www/cen2000.html [August 2004].

Burke, L. M. (1993, October). Race and environmental equity: A geographic analysis in Los Angeles. *GeoInfo Systems*, pp. 44–50.

California Air Resources Board. (2003a). *Proposed 2003 state and federal strategy for the California state implementation plan*. Available:http://www.arb.ca.gov/planning/sip/stfed03/revsect5.pdf [May 2004].

California Air Resources Board. (2003b). Current emissions and air quality–criteria pollutants. In *The 2003 California almanac of emissions and air quality* (pp. 45–92). Available: http://www.arb.ca.gov/aqd/almanac/almanac03/pdf/chap203.pdf [August 2004].

California Air Resources Board and California Office of Environmental Health Hazard Assessment. (2002). *Staff report: Public hearing to consider amendments to the ambient air quality standards for particulate matter and sulfates*. Available: http://www.arb.ca.gov/research/aaqs/std-rs/pm-final/pmfinal.htm [March 2004].

California Air Resources Board and California American Lung Association of California (2004, January). *Recent research findings: Health effects of particulate matter and ozone air pollution*. Available: http://www.arb.ca.gov/research/health/fs/PM-03fs.pdf [October 2004].

California Department of Transportation. (2000). *Highway performance and monitoring system*. Available: http://www.dot.ca.gov/hq/tsip/hpms/program.html [June 2004].

California Department of Transportation. (2002). *Traffic counts from the traffic and vehicle data systems unit*. Available: http://www.dot.ca.gov/hq/traffops/saferesr/trafdata/index.htm [March 2004].

California Environmental Protection Agency and California Air Resources Board (2004). *Draft air quality and land use handbook: A community health perspective*. Available: http://www.arb.ca.gov/ch/ej_meetings/may_10_2004_draft_land_use_handbook.pdf [May 2004].

California Statewide Database. (2003). *2001 tax assessor data files*. Available: http://swdb.berkeley.edu/ [July 2004].

Colome, S. D., Wilson, A. L., & Tian, Y. (1994). *California residential indoor air quality study. Volume 2: Carbon monoxide and air exchange rate: A univariate and multivariate analysis*. Final report to Gas Research Institute, Pacific Gas and Electric Company, San Diego Gas and Electric Company and Southern California Gas Company. Irvine, California: Integrated Environmental Services.

Cutter, S. L., & Solecki, W. D. (1996). Setting environmental justice in space and place: acute and chronic airborne toxic releases in the Southeastern United States. *Urban Geography*, *17*, 380–399.

Duhme, H., Weiland, S. K., Keil, U., Kraemer, B., Schmid, M., Stender, M., & Chambless, L. (1996). The association between self-reported symptoms of asthma and allergic rhinitis and self-reported traffic density on street of residence in adolescents. *Epidemiology*, *7*(6), 578–582.

Edwards, J., Walters S., & Griffiths R. K. (1994). Hospital admissions for asthma in preschool children: relationship to major roads in Birmingham, United Kingdom. *Archives of Environmental Health*, *49*(4), 223–7.

Frey, W. H., & Farley, R. (1996). Latino, Asian, and black segregation in U.S. metropolitan areas: Are multi-ethnic metros different? *Demography*, *33*(1), 35–50.

Geronimus, A. T. (2000). To mitigate, resist, or undo: addressing structural influences on the health of urban populations. *American Journal of Public Health*, *90*, 867–872

Gunier, R., Hertz, A., Von Behren, J., & Reynolds, P. (2003). Traffic density in California: Socioeconomic and ethnic differences among potentially exposed children. *Journal of Exposure Analysis and Environmental Epidemiology*, *13*, 240–246.

Hall, J. V., Winer, A. M., Kleinman, T., Lurmann, F. W., Brajer, V., & Colome, S. D. (1992). Valuing the health benefits of clean air. *Science*, *255*, 812–817.

Hitchins, J., Morawska, L., Wolff, L., & Gilbert, D. (2000). Concentration of submicrometer particles from vehicle emissions near a major road. *Atmospheric Environment*, *34*, 51–59.

Hoek, G., Brunekreef, B., Goldbohm, S., Fischer, P., & van den Brandt, P. (2002). Association between mortality and indicators of traffic-related air pollution in the Netherlands: A cohort study. *Lancet*, *360*(9341), 1203–1209.

Jaret, C., Reid, L., & Adelman, R. (2003). Black-white income inequality and metropolitan socioeconomic structure. *Journal of Urban Affairs*, *25*(3), 305–333.

Jargowsky, P. (1997). *Poverty and place: Ghettos, barrios, and the American city*. New York: Russell Sage Foundation.

Jargowsky, P. (2003). *The stunning progress, hidden problems: The dramatic decline of concentrated poverty in the 1990s*. Washington, DC: Brookings Institution.

Kawachi, I., & Berkman, L. F. (2003). *Neighborhood and health*. New York: Oxford University Press.

Klepeis, N. E., Nelson, W. C., Ott, W. R., Robinson, J. P., Tsang, A. M., Switzer, P., Behar, J. V., Hern, S. C., & Engelmann, W. H. (2001). The National Human Activity Pattern Survey (NHAPS): A resource for assessing exposure to environmental pollutants. *Journal of Exposure Analysis and Environmental Epidemiology*, *11*, 231–252.

Knox, E. G., & Gilman, E. A. (1997). Hazard proximities of childhood cancers in Great Britain from 1953–1980. *Journal of Epidemiology and Community Health*, *51*, 151–159.

Lejano, R., & Iseki, H. (2001). Environmental justice: Spatial distribution of hazardous waste treatment, storage, and disposal facilities in Los Angeles. *Journal of Urban Planning and Development*, *127*(2), 51–62.

Lejano, R., Piazza, B., & Houston, D. (2002). Rationality as social justice and the spatial-distributional analysis of risk. *Environment and Planning C: Government and Policy*, *20*, 871–888.

Lin, S., Munsie, J. P., Hwang, S., Fitzgerald, E., & Cayo, M. R. (2002). Childhood asthma hospitalization and residential exposure to state route traffic. *Environmental Research, Section A*, *88*, 73–81.

Logan, J., & Molotch, H. (1987). *Urban fortunes: The political economy of place*. Berkeley, CA: University of California Press.

Los Angeles County Metropolitan Authority. (2003). *Draft 2003 short range transportation plan for Los Angeles County*. Available: www.metro.net/projects_plans/shortrange/images/2003_SRTP.pdf [August 2004].

Maantay, J. (2002). Mapping environmental injustices: Pitfalls and potential of geographic information systems in assessing environmental health and equity. *Environmental Health Perspectives*, *110*, 161–171.

Massey, D., & Denton, N., (1987). Trends in the residential segregation of blacks, Hispanics, and Asians: 1970–1980. *American Sociological Review*, *52*, 802–825.

Massey, D., & Denton, N., (1993). *American apartheid: Segregation and the making of the underclass*. Cambridge, MA: Harvard University Press.

McConville, S., & Ong, P. (2001). *Examining residential segregation patterns*. Discussion Paper. The Ralph and Goldy Lewis Center for Regional Policy Studies, University of California, Los Angeles. Available: http://lewis.sppsr.ucla.edu/index.cfm [November 2003].

McConville, S., & Ong, P. (2003). *The trajectory of poor neighborhoods in Southern California, 1970–2000*. Washington, DC: Brookings Institution.

Morello-Frosch, R. (2002). Discrimination and the political economy of environmental inequality. *Environment and Planning C: Government and Policy*, *20*, 477–496.

Morello-Frosch, R., Pastor, M., Jr., & Sadd, J. (2001). Environmental justice and southern California's "riskscape": The distribution of air toxics exposures and health risks among diverse communities. *Urban Affairs Review*, *36*(4), 551–578.

Morello-Frosch, R., Pastor, M., Jr., Porras, C., & Sadd, J. (2002). Environmental justice and regional inequality in Southern California: Implications for future research. *Environmental Health Perspectives*, *110*, 149–154.

Myers, D. (2001). Demographic futures as a planning guide; California's Latinos and the compact city. *Journal of the American Planning Association*, *67*(4), 383–397.

Nordlinder R., & Jarvholm, B. (1997). Environmental exposure to gasoline and leukemia in children and young adults–An ecology study. *International Archives of Occupational and Environmental Health*, *70*, 57–60.

Ong, P. (2002). Car ownership and welfare-to-work. *Journal of Policy Analysis and Management*, *21*(2), 255–268.

Ong, P., & Sung, H. (2003). *Exploratory study of spatial variation in car insurance premiums, traffic volume and vehicle accidents*. University of California Transportation Center Report No. 654. Berkeley, California: University of California Transportation Center.

Oosterlee, A., Drijver, M., Lebret, E., & Brunekreef, B. (1996). Chronic respiratory symptoms of children and adults living along streets with high traffic density. *Occupational and Environmental Medicine*, *53*, 241–247.

Pastor, M., Jr., Sadd, J., & Hipp, J. (2001). Which came first? Toxic facilities, minority move-in, and environmental justice. *Journal of Urban Affairs*, *21*, 1–21.

Pastor, M., Jr., Sadd, J., & Morello-Frosch, R. (2002). Who's minding the kids? Pollution, public schools, and environmental justice in Los Angeles. *Social Science Quarterly*, *83*(1), 263–280.

Paustenbach, D. J. (2000). The practice of exposure assessment: A state-of-the-art review. *Journal of Toxicology and Environmental Health. Part B*, *3*, 179–291.

Pearson, R. L., Wachtel, H., & Ebi, K. L. (2000). Distance-weighted traffic density in proximity to a home is a risk factor for leukemia and other childhood cancers. *Journal of the Air Waste Management Association*, *50*, 175–180.

Pettit, K. L. S., Kingsley, G. T., & Coulton, C. J. (2003). *Neighborhoods and health: Building Evidence for local policy*. Washington, DC: The Urban Institute.

Pulido, L. (2000). Rethinking environmental racism: White privilege and urban development in Southern California. *Annals of the Association of American Geographers*, *90*(1), 12–40.

Pulido, L., Sidawi, S., & Vos, R. O. (1996). An archeology of environmental racism in Los Angeles. *Urban Geography*, *17*, 419–439.

Rodes, C., Sheldon, L., Whitaker, D., Clayton, A., Fitzgerald, K., Flanagan, J., DiGenova, F., Hering, S., & Frazier, C. (1998). *Measuring concentrations of selected air pollutants inside California vehicles*. Final Report, Contract No. 95–399. California Air Resources Board, Research Division, CA.

Romo, R. (1983). *East Los Angeles; History of a barrio*. Austin: University of Texas Press.

S. 352, Schoolsites: Sources of Pollution, California (2003). Available: http://www.leginfo.ca.gov/pub/bill/sen/sb_0351-0400/sb_352_bill_20030911_enrolled.html [September 2004].

Sadd, J. L., Pastor, M., Jr., Boer, J. T., & Snyder, L. D. (1999). Every breath you take: The demography of toxic air releases in southern California. *Economic Development Quarterly*, *13*(2), 107–123.

Savitz, D. A., & Feingold, L. 1989. Association of childhood cancer with residential traffic density. *Scandinavian Journal of Work, Environment and Health*, *15*, 360–363.

South Coast Air Quality Management District. (1999). *Multiple air toxics exposure study in the South Coast Air Basin–MATES-II*. Diamond Bar, CA: South Coast Air Quality Management District.

South Coast Air Quality Management District. (2003). *2003 Draft air quality management plan*. Diamond Bar, CA: South Coast Air Quality Management District.

Southern California Association of Governments. (SCAG). (2003). *2000 existing land use data files* Available: http://mapsvr.scag.ca.gov/wags/index.cfm [June 2004].

Southern California Association of Governments. (SCAG). (2004). *2004 Regional transportation plan*. Los Angeles, CA: Southern California Association of Governments.

Squires, G. (2003). Racial profiling, insurance style: Insurance redlining and the uneven development of metropolitan areas. *Journal of Urban Affairs*, *25*(4), 391–410.

Turner, M. A., Ross, S. L., George C. G., & Yinger, J. (2002). *Discrimination in metropolitan housing markets: Phase 1*. Washington, DC: The Urban Institute.

Turner, M. A., & Ross, S. L. (2003). *Executive summary: Discrimination in metropolitan housing markets: Phase 2–Asian and Pacific Islander*. Washington, DC: The Urban Institute.

van Vliet, P., Knape, M., de Hartog, J., Janssen, N., Harssema, H., & Brunekreef, B. (1997). Motor vehicle exhaust and chronic respiratory symptoms in children living near freeways. *Environmental Research*, *74*(2), 122–32.

Venn, A. J., Lewis S. A., Cooper, M., Hubbard, R., & Britton, J. (2001). Living near a main road and the risk of wheezing illness in children. *American Journal of Respiratory and Critical Care Medicine*, *164*, 2177–2180.

Wilhelm, M., & Ritz, B. (2003). Residential proximity to traffic and adverse birth outcomes in Los Angeles County, California, 1994–1996. *Environmental Health Perspectives*, *111*, 207–216.

Wilson, W. J. (1987). *The truly disadvantaged: The inner city, the underclass, and public policy*. Chicago: University of Chicago Press.

Wright, J. W., & Ficher, B. F. (2003). Putting asthma into context: Community influences on risk, behavior, and intervention. In I. Kawachi & L. F. Berkman (Eds.), *Neighborhood and health* (pp. 233–262). New York: Oxford University Press.

Wu, J., Lurmann, F., Winer, A., Lu, R., & Turco, R. (in press). *Development of an individual exposure model for use in epidemiological studies: Application to the USC Children's Health Study*. *Atmospheric Environment*.

Zhu, Y., Hinds, W. C., Kim, S., & Sioutas, C. (2002). Concentration and size distribution of ultrafine particles near a major highway (405). *Journal of the Air & Waste Management Association*, *52*, 1032–1042.