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Proximity of California Public Schools to Busy Roads

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Residential proximity to busy roads has been associated with adverse health outcomes, and school location may also be an important determinant of children's exposure to traffic-related pollutants. The goal of this study was to examine the characteristics of public schools (grades K–12) in California (*n* = 7,460) by proximity to major roads. We determined maximum daily traffic counts for all roads within 150 m of the school using a statewide road network and a geographic information system. Statewide, 173 schools (2.3%) with a total enrollment of 150,323 students were located within 150 m of high-traffic roads (≥ 50,000 vehicles/day); 536 schools (7.2%) were within 150 m of medium-traffic roads (25,000–49,999 vehicles/day). Traffic exposure was related to race/ethnicity. For example, the overall percentage of nonwhite students was 78% at the schools located near high-traffic roads versus 60% at the schools with very low exposure (no streets with counted traffic data within 150 m). As the traffic exposure of schools increased, the percentage of both non-Hispanic black and Hispanic students attending the schools increased substantially. Traffic exposure was also related to school-based and census-tract–based socioeconomic indicators, including English language learners. The median percentage of children enrolled in free or reduced-price meal programs increased from 40.7% in the group with very low exposure to 60.5% in the highest exposure group. In summary, a substantial number of children in California attend schools close to major roads with very high traffic counts, and a disproportionate number of those students are economically disadvantaged and nonwhite. *Key words:* air pollution, children's health, environmental justice, ethnicity, schools, socioeconomic status, traffic. *Environ Health Perspect* 112:61–66 (2004). doi:10.1289/ehp.6566 available via *http://dx.doi.org/* [Online 7 October 2003]

Vehicular-traffic–related emissions are a major source of air pollution, especially in urban areas. Epidemiologic studies of the relationship between asthma prevalence or morbidity and traffic-related exposures have recently been reviewed (Delfino 2002). Residential proximity to busy roads has been associated with respiratory symptoms (Ciccone et al. 1998; van Vliet et al. 1997; Venn et al. 2000, 2001), asthma hospitalizations (Edwards et al. 1994), and decreased lung function in children (Brunekreef et al. 1997). A study in San Diego, California (English et al. 1999), found increased risks for medical visits for asthmatic children associated with residence near at least one busy street. Some studies have found associations between proximity to traffic and higher rates of childhood cancer (Pearson et al. 2000; Raaschou-Nielsen et al. 2001; Savitz and Feingold 1989), whereas others have failed to show any association (Langholz et al. 2002; Reynolds et al. 2002).

A study of vehicular traffic density in census block groups in California (Gunier et al. 2003) found that children of color were about three times more likely to live in high-traffic areas than were white children. Researchers examining stationary sources of air pollution, such as Toxic Release Inventory (TRI) facilities, have found evidence of disproportionate exposures by race and socioeconomic status (Maantay 2002; Morello-Frosch et al. 2002a). Another study found that nonwhite students in southern California were more likely than non-Hispanic whites to attend schools in locations with higher respiratory risks, estimated from modeled concentrations of hazardous outdoor air pollutants emitted by both mobile and stationary sources (Morello-Frosch et al. 2002b).

School location may be an important determinant of exposure to traffic-related pollutants because children spend much of their time at school. There are more than 8,000 public schools in California, but to date no one has assessed either the spatial distribution or the demographic profiles of schools in relation to nearby vehicular traffic volume. The goal of this study was to examine the characteristics of public schools in California by proximity to busy roads and to determine whether there are disparities in proximity of schools to high traffic volumes by race/ethnicity and socioeconomic status.

Materials and Methods

School data and selection. For this study, we used the most current database available from the California Department of Education (CDE) as of December 2000 (CDE 2000). From this statewide school database of approximately 8,200 schools, we selected all open public schools, grades K–12, excluding alternative and special education; 7,515 schools met the eligibility criteria. The school database also included *a*) school address, *b*) school district, *c*) county, *d*) census tract in which the school was located, *e*) type of school (e.g., elementary school, middle school, high school), *f*) total enrollment by grade and race/ethnicity, *g*) number of students eligible for free/reduced-price meals (which is related to household income and size), *h*) number of children 5–17 years old residing in the school's attendance area who are eligible for the California Work Opportunity and Responsibility to Kids program (CalWORKS; aid for families and welfare-to-work program), and *i*) total number and native language of English learners (i.e., children whose primary language is not English and who have been assessed to lack English language skills). Except for the CalWORKS indicator, all other demographic data are based on student enrollment information obtained by the school.

Census data. We downloaded the Census 2000 Summary File 3 data from the U.S. Census Bureau American FactFinder website (U.S. Census Bureau 2002). We compiled demographic, social, economic, housing, and population density data and calculated proportions of individuals in a census tract possessing each characteristic (e.g., race, income below poverty level, birthplace outside the United States). These data were used to delineate the sociodemographic composition of the census tracts in which the schools were located.

Geocoding of schools. The addresses of all the schools were geocoded using Maptitude, version 4.2, and a street network provided with the software (Caliper Corporation, Newton, MA). We used an offset of 25 feet (~8 m) from the street centerline to locate the school. The geographic information system (GIS) software identifies the street block that matches the address and uses an interpolation method to place the point within an address range. Schools still unmatched after the batch process (468 total) were then checked against other street address resources, such as Street Atlas USA, version 9.0 (DeLorme, Yarmouth, ME) and ZP4 (Semaphore Corporation,

Aptos, CA); we then manually transferred this information to Maptitude for geocoding. Ultimately, 7,460 of the 7,515 schools (> 99%) were successfully located and assigned a longitude and latitude. A number of the nongeocoded schools did not have addresses in the CDE database. Others were in rural areas without numerical addresses or in fast-growing areas with new streets. Finally, the schools master file was converted to a point shape file for use in ArcView 3.2a GIS software (Environmental Systems Research Institute, Redlands, CA).

Traffic database. The traffic database, obtained from the California Department of Transportation (CalTrans), contained traffic and various road data for discrete road segments in California. The source of these data was the 1997 Highway Performance Monitoring System (HPMS) maintained by CalTrans (CalTrans 1997). The HPMS traffic database has been described previously in several recent epidemiologic studies of traffic and adverse health outcomes (English et al. 1999; Gunier et al. 2003; Wilhelm and Ritz 2003). For this study, we used the average annual daily traffic (AADT) of the road segment, which is two-way traffic volume adjusted for day-of-week, seasonal, and growth factors. Only freeways, highways, major arterial roads, and large collector roads are included in the HPMS database. Collector roads are main streets in communities that lead to the residential streets. CalTrans periodically undertakes traffic counts on some roads and then estimates or extrapolates traffic flow to others, assigning AADT to each road segment. There are no traffic flow data for local residential streets.

GIS analysis. All georeferenced data were stored in decimal degrees and were standardized to the North American Datum for 1983, a set of parameters and control points used to accurately define the three-dimensional shape of Earth. The schools and CalTrans traffic files were overlaid in ArcView, and an equidistant projection was performed in order to avoid distance distortion. Then the distances from each school to all road segments within a 150-m buffer around the school were calculated using ArcView 3.2a. Distance was estimated as the shortest planar distance between the point (school) and the line (road segment with traffic counts; Figure 1). The last step was to overlay the full schools file with 2000 census tracts and assign each school a census tract number.

Exposure assessment. Several studies have shown that the concentration of traffic pollutants drops off rapidly with increasing distance downwind from the road, with the most rapid decline occurring within 150 m of the road (Hitchins et al. 2000; Zhu et al. 2002a, 2002b). A recent study in Los Angeles (Zhu et al. 2002b) found that concentrations of ultrafine particles, black carbon, and carbon

monoxide decreased exponentially with distance downwind of a major freeway. Concentrations measured 150 m downwind of the freeway were close to background levels, whereas those measured 300 m downwind were indistinguishable from upwind background concentrations. Additionally, epidemiologic studies have reported associations between increasing traffic counts on nearby roads and decreased lung function, respiratory disease, and asthma hospitalizations in children (Brunekreef et al. 1997; Ciccone et al. 1998; Edwards et al. 1994; English et al. 1999; Pearson et al. 2000; Raaschou-Nielsen et al. 2001; Savitz and Feingold 1989; van Vliet et al. 1997; Venn et al. 2000, 2001; Wjst et al. 1993). Distance to the nearby road varied by study but generally ranged from 100 m (van Vliet et al. 1997) to 500 m (Edwards et al. 1994), and adverse effects were reported for traffic counts starting at about 24,000 vehicles/day (Edwards et al. 1994; Wjst et al. 1993).

On the basis of these findings, we selected the road segment with the maximum AADT within 150 m of each school as an estimate of exposure to traffic (Figure 2). High exposure to nearby traffic was defined as ≥ 50,000 vehicles/day on any road segment within 150 m of the school; medium exposure 25,000–49,999 vehicles; and low exposure < 25,000 vehicles. Schools not having any streets with counted traffic volume within 150 m were assigned to the very-low-exposure category. The school in Figure 2 would be in the low-traffic-exposure category.

Statistical analyses. We first evaluated associations between variables obtained from the school and traffic databases [e.g., urban/rural location, school demographics (race, ethnicity, economic disadvantage), and type of school] and the four traffic categories (i.e., very low, low, medium, and high exposures). Although there were few measures of economic disadvantage in the school database, several socioeconomic variables were available from the census-tract–level data. Because there were

strong associations between the continuous school-level and corresponding census-tract–level demographic variables, as calculated with Pearson's product moment correlations, we also used the following census-tract–level data in our analyses: population density, percentage of households with income below the poverty level, percentage of people 25 years or older with no high school diploma, and percentage of persons born abroad.

To evaluate relationships between traffic categories and both school-level and census-tract–level variables, we performed polytomous logistic regression using SAS software (version 8.2 for Windows; SAS Institute Inc., Cary, NC). Specifically, using race, ethnicity, and socioeconomic status as explanatory variables, we modeled *a*) the odds of a school belonging to the high traffic category compared with the low and very low categories combined and *b*) the odds of a school belonging to the medium traffic category compared with the very low and low categories combined. We computed odds ratios (ORs) for a 25% increase in each demographic variable except population density, which was log transformed because of its skewed distribution.

We also examined the association between traffic and race/ethnicity after stratifying schools into two groups: those above and those below the median percentage of students receiving free/reduced-price meals. Finally, we performed a separate analysis of the data after restricting schools to those located in Los Angeles County census tracts with a population density of at least 5,000 people per square mile. In this way, we could examine whether the relationships between exposure to traffic at school and race/ethnicity or economic disadvantage in a highly urbanized area were similar to those seen statewide.

Results

Statewide, 173 schools (2.3%) with a total enrollment of 150,323 students (2.6%) had high exposure to nearby traffic, 536 schools (7.2%) had medium exposure, 4,484 schools
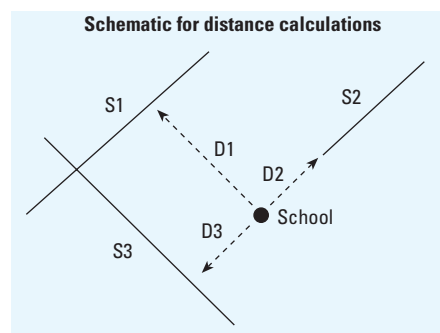
Figure 1. Schematic diagram of distance calculations (D1–D3) between a school and three road segments (S1–S3). This example shows that the distance between the school and S*i* is D*i*.
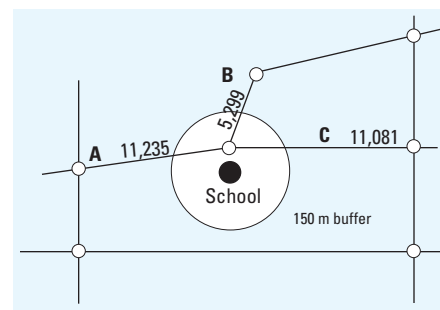
Figure 2. Schematic diagram of a school and three road segments with attributed traffic volume (number of vehicles per day) within a 150-m buffer of the school. Segment A would be chosen for the analysis, because it has the highest AADT.

(60.1%) had low exposure, and 2,267 schools (30.4%) had very low exposure (Table 1). The percentage of children enrolled in schools in each of the traffic exposure categories, except the category with no attributable traffic, was somewhat larger than the percentage of schools with these levels of traffic (Figure 3). Similar proportions of elementary and middle schools were close to medium or high traffic. A higher percentage of high schools than elementary or middle schools was close to medium traffic (12.2%). Of the 49 schools that combined grades K–12, 20.4% had medium or high exposure to nearby traffic versus 9.5% of schools statewide.

Most schools close to high traffic volume were in large urban areas, but several schools in small urban and rural areas were also close to busy roads. The percentage of schools near medium and high traffic increased with increasing population density per square mile (Table 1). However, some schools in the lowest quartile of population density were close to medium or high traffic.

Race/ethnicity was related to traffic exposure (Figure 4). As the traffic exposure category increased, the percentages of Hispanic and of non-Hispanic black children attending schools in those categories increased, and the percentage of non-Hispanic white children decreased. There was little difference in the percentages of Asian children across traffic categories. Economic disadvantage was also related to traffic exposure (Figure 5). The median percentage of children participating in CalWORKS in the schools' attendance areas increased steadily from 8.9% in schools with very low exposure to 15.5% in those with high exposure. Similarly, the median percentage of children enrolled in free or reduced-price meal programs increased from 40.7% in the group with very low exposure to 60.5% in the highest exposure group. The median percentage of

children whose primary language was not English and who had been assessed to lack English language skills also rose steadily with increasing traffic. Similar patterns were also observed when the analysis was restricted to schools in Los Angeles County census tracts with population densities of at least 5,000 people per square mile.

The school-level and corresponding census-tract–level demographic variables were highly correlated. The Pearson correlation coefficients for percent Hispanic, percent non-Hispanic black, percent non-Hispanic white, percent Asian, and percent English learners at school versus in the host census tract were, respectively, 0.88, 0.82, 0.87, 0.77, and 0.76. The correlation coefficient for percentage receiving free or reduced-price meals, a school-based variable, and percentage with family income below poverty, a census tract variable, was 0.61. Based on these results, we considered it reasonable to use several census-tract–level variables not available in the school database in additional analyses.

Table 2 shows the results of the polytomous logistic regression analyses modeling the odds of belonging to the high-traffic and to the medium-traffic categories compared with the combined low and very low categories, given population density in the surrounding tract, ethnic composition of the school, and the school-level and census-tract–level socioeconomic status variables. Except for population density, the ORs shown are for a 25% change in the independent variable. Based on the standardized regression coefficients, measured as the change in the log-odds of traffic category for a one standard deviation increase in the independent variable (Selvin 1996), population density per square mile of land in the surrounding census tract was the strongest predictor of traffic category, followed by percentage born abroad, another tract-level variable. The OR for a 25%

increase in percentage born abroad was 2.52 [95% confidence interval (CI), 2.00–3.17] for 50,000 vehicles compared with < 25,000 vehicles; the OR for 25,000–49,999 vehicles versus < 25,000 vehicles was 2.23 (95% CI, 1.94–2.56). All the measures of low socioeconomic status—including percentage receiving free/reduced-price meals at school, percentage with income below poverty level in the census tract, and percentage with no high school diploma in the census tract—were also strongly positively associated with high and medium traffic within 150 m of school. Percent black and percent Hispanic at the school were strongly related to traffic category, whereas percent Asian was positively associated with exposure to medium traffic (AADT = 25,000–49,000) but not with exposure to high traffic. The OR for a 25% increase in percent black was 1.51 (95% CI, 1.21–1.89) for 50,000 vehicles compared with < 25,000 vehicles; the OR for 25,000–49,999 vehicles versus < 25,000 vehicles was 1.38 (95% CI, 1.19–1.59). The OR for a 25% increase in percent Hispanic was 1.45 (95% CI, 1.28–1.64) for 50,000 vehicles compared with < 25,000 vehicles; the OR for 25,000–49,999 vehicles versus < 25,000 vehicles was 1.25 (95% CI, 1.16–1.35).
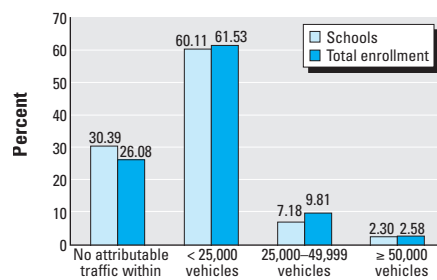
Figure 3. Percentage of schools and percentage of total enrollment for California public schools (K–12) in 2000, by maximum AADT within 150 m of school.

Table 1. Maximum AADT within 150 m of California public schools (K–12) in 2000 by enrollment, school type, degree of urbanization, and population density.

	No attributable traffic within 150 m n (%)	< 25,000 vehicles n (%)	25,000–49,999 vehicles n (%)	≥ 50,000 vehicles n (%)
Total enrollment	1,518,205 (26.1)	3,582,263 (61.5)	571,040 (9.8)	150,323 (2.6)
Total schools	2,267 (30.4)	4,484 (60.1)	536 (7.2)	173 (2.3)
School type				
Elementary	1,781 (33.5)	3,090 (58.1)	326 (6.1)	122 (2.3)
Middle school	309 (26.4)	740 (63.2)	91 (7.8)	31 (2.7)
High school	161 (17.5)	631 (68.5)	112 (12.2)	17 (1.9)
K–12	16 (32.7)	23 (46.9)	7 (14.3)	3 (6.1)
Degree of urbanization				
Rural (< 5,000 people)	369 (35.1)	670 (63.8)	8 (0.8)	4 (0.4)
Small urban (5,000–50,000 people)	182 (25.6)	524 (73.7)	4 (0.6)	1 (0.1)
Urban (50,000–200,000 people)	164 (26.8)	418 (68.2)	24 (3.9)	7 (1.1)
Large urban (> 200,000 people)	1,442 (29.0)	2,872 (57.7)	500 (10.1)	161 (3.2)
Population density[a]				
Quartile 1 (< 1,211)	711 (38.1)	1,104 (59.2)	32 (1.7)	18 (1.0)
Quartile 2 (1,211–4,849)	603 (32.3)	1,133 (60.8)	98 (5.3)	31 (1.7)
Quartile 3 (4,850–8,371)	531 (28.5)	1,129 (60.5)	149 (8.0)	56 (3.0)
Quartile 4 (8,372–96,271)	421 (22.6)	1,118 (60.0)	257 (13.8)	68 (3.7)

[a]Population per square mile of land in surrounding census tract in 2000.

When we stratified the analyses by percentage of students receiving free/reduced-price meals (above and below the median value of 46.9%), the ORs within strata were very similar to those based on all schools for all ethnic groups and for English learners. For example, the OR for a 25% increase in percent Hispanic at schools where < 46.9% of students received free/reduced-price meals was 1.59 (95% CI, 1.26–2.0) for ≥ 50,000 vehicles compared with < 25,000 vehicles, whereas the OR for the same traffic category comparison at schools above the median was 1.31 (95% CI, 1.09–1.58).

Discussion

This is the first study to examine proximity of California public schools to busy roads. We found that close to 10% of California public schools, enrolling 721,363 children (12.4% of students), are close to medium or high traffic volume, defined as being within 150 m of a road segment with AADT of 25,000 or more vehicles. Most schools near high traffic are located in large urban areas; however, this phenomenon can be observed in small urban and rural locations as well. Furthermore, disproportionate numbers of nonwhite and economically disadvantaged students attend schools near high traffic volumes. In addition, we found that schools that are in close proximity to high traffic volumes are more likely than those farther away from busy roads to be located in economically disadvantaged census tracts. We also found a strong association between proximity of a school to high traffic volume and both percentage of English learners at the school and percentage of foreign-born persons living in the surrounding census tract. This is the first published study of which we are aware that suggests that immigrants are more likely than U.S.-born citizens to live or attend schools near a source of environmental pollution. The positive associations of proximity to high traffic volume with race/ethnicity and English language competency persisted even after stratifying by a school-based measure of economic disadvantage. Our findings support those of the California study (Gunier et al. 2003), which found that, on the basis of residential exposure profiles, nonwhites are more likely to be exposed to high traffic density. Other researchers have found evidence of disproportionate exposures by race or socioeconomic status in the siting of stationary sources of air pollutants, such as TRI facilities and treatment, storage, and disposal facilities (TSDFs). A review of 13 GIS-based environmental equity studies conducted from 1993 to 1999 either nationwide or in several individual states (Maantay 2002) found that all the studies showed a disproportionate number of non-white persons living near environmental hazards such as TRI facilities and TSDFs.

In several of these studies, income was also inversely related to proximity to environmental hazards.

A study in southern California (Morello-Frosch et al. 2002a) reported significant demographic differences between census tracts in Los Angeles hosting or located within a 1-mile radius of a TSDF and those without TSDFs. Those with TSDFs had significantly greater percentages of nonwhite residents, especially Hispanics; lower per capita income; and lower household income. The authors of that study also found that minority students, especially Hispanics, were more likely than non-Hispanic whites to attend schools in locations with higher estimated respiratory risks modeled from concentrations of outdoor air pollutants. Children attending these schools had lower academic performance scores than did those attending schools in locations with low respiratory risk, even after controlling for several measures of poverty, English-language competence,
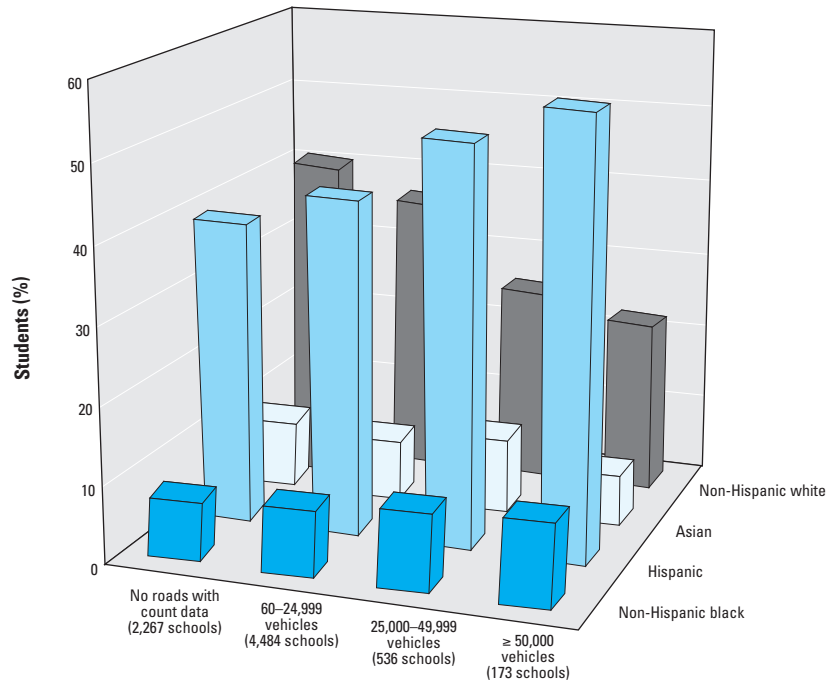
Figure 4. Percentage of all California public school (K–12) students in 2000, by ethnicity, in relation to maximum AADT within 150 m of school.
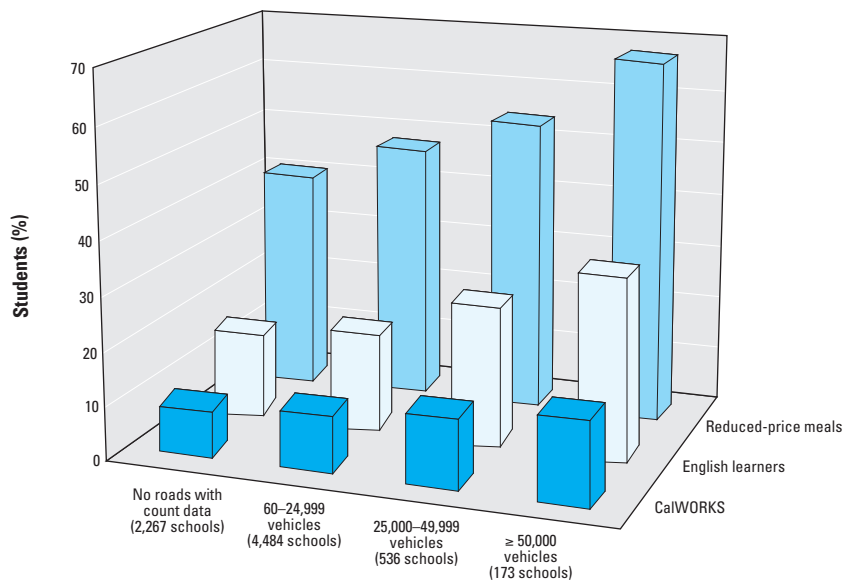
Figure 5. Median percentage of California public school (K–12) students participating in programs for economically disadvantaged students and whose primary language is not English, in 2000, by maximum AADT within 150 m of school.

and parental educational attainment (Morello-Frosch et al. 2002b).

Our finding that about 721,363 California students (12.4% of the total statewide) attend public schools located within 150 m of a busy road has important health implications. Several European studies have found adverse health effects in children residing or attending school in close proximity to roads with AADT of 25,000 or more vehicles. A study of German school children (Wjst et al. 1993) found a decrease in peak expiratory flow of 0.71% (95% CI, 0.33–1.08%) per increase of 25,000 cars daily on roads with the highest traffic volume passing through the school district. That study also found that increasing traffic volume was associated with recurrent wheezing (adjusted OR/25,000 cars = 1.08; 95% CI, 1.01–1.16) and recurrent dyspnea (adjusted OR/25,000 cars = 1.10; 95% CI, 1.00–1.20). A case–control study of hospital admissions for asthma in Birmingham (U.K.; Edwards et al. 1994) found that cases were more likely to live near a road with high traffic (> 24,000 cars/day) than were community controls (OR = 1.4; 95% CI, 1.13–1.74). Furthermore, they found a significant linear trend in hospital admissions with increasing traffic for subjects living less than 500 m from a major road ($p <$ 0.006). However, only unadjusted results were reported. A study conducted in San Diego, California (English et al. 1999), found an almost 3-fold increase (OR = 2.91; 95% CI, 1.23–6.91) in medical care visits for asthmatic children for whom the traffic flow on the nearest street within 168 m was 41,000 vehicles per day and a moderately increased OR (1.85, 95% CI; 0.92–3.71) for 21,200 or more vehicles per day. Because children spend many hours per day at school, both in the classroom and outside at play or participating in rigorous sports, school proximity to large traffic volumes may increase children's risk of adverse respiratory and other health outcomes.

The traffic volume and distance cut points used in this analysis are based on the results of both epidemiologic studies and studies monitoring the air dispersion of traffic-related pollutants, and they represent a reasonable basis for an initial categorization of California public schools in relation to traffic. Other traffic metrics, such as the sum of traffic within a buffer, distance-weighted traffic density, or the traffic count at the nearest road have been used in epidemiologic studies (English et al. 1999; Wilhelm and Ritz 2003). However, we felt that the maximum traffic within 150 m would be a reasonable, easy-to-visualize metric for a descriptive study of proximity to traffic and would be a more practical metric for school site planning. To date, no good studies have compared the relation of different traffic metrics to actual exposure to traffic-related pollutants. Most of the epidemiologic studies have been conducted in Europe, where fleet composition and other factors affecting traffic emissions differ, and further studies are needed to quantify traffic volumes that may be associated health effects in children in the United States.

Several studies suggest that residential proximity to truck traffic may be more strongly associated with adverse health effects compared with total vehicular traffic (Brunekreef et al. 1997; Duhme et al. 1996; van Vliet et al. 1997; Weiland et al. 1994). Unfortunately, the CalTrans database did not include complete data on truck or bus traffic. Additionally, we were not able to take into account prevailing wind direction, topography, or climate, all of which can affect exposure to traffic-related pollutants.

Although the development of GIS software allowed us to determine the traffic volume nearby for more than 98% of schools that were eligible for study, this method does have some limitations. First, the street linework layer used to geocode the school addresses did not align perfectly with the street linework from CalTrans, which contains the traffic volume data. This would cause some incorrect distance calculations. The misalignment is difficult to quantify on a statewide basis because it varies by region of the state with no consistent pattern. It would have been too labor intensive to actually determine the degree of misalignment between the CalTrans street linework and the street linework provided with Maptitude for each of the nearly 8,000 schools in this study. If this error were randomly distributed, it would not cause differential misclassification. The associations we saw between traffic and race/ethnicity statewide were similar to those we saw when we restricted our analysis to schools in Los Angeles County census tracts with population density of at least 5,000 people per square mile. This suggests that there were no systematic errors in calculating distances to roads in urban areas. However, random errors could have biased toward the null the associations we found between traffic and factors such as ethnicity and socioeconomic status.

Second, in reality a school is not a point (as assumed in the geocoding process) but extends over a large area (i.e., is a polygon). Similarly, a road is not a line but a "ribbon." Schools are geocoded based on the address of the administration building, but this point does not represent the actual location of children at school, which can vary by classroom and activity. Consequently, the distance from a school to a road as calculated by GIS is an approximation of the distance from where the students are to the road. If we had increased the buffer size, we may have captured some road segments that were actually close to one boundary of the school property, but we would have also included roads that were potentially much farther from the schools.

Third, there are problems inherent in the geocoding process itself. The offset we used assumes that all school buildings are located 25 feet from the center of the street. Depending on where different school campus

Table 2. Odds of close proximity to high and to medium traffic by demographic characteristics of California public schools (K–12) and surrounding census tracts in 2000.

Variables	Maximum AADT[a]	Standardized coefficient[b]	OR[c] (95% CI)
School-level variables			
Percent nonwhite[d]	≥ 50,000	0.34	1.69 (1.46–1.97)
	25,000–49,999	0.25	1.48 (1.36–1.61)
Percent black[d]	≥ 50,000	0.11	1.51 (1.21–1.89)
	25,000–49,999	0.09	1.38 (1.19–1.59)
Percent Hispanic[d]	≥ 50,000	0.24	1.45 (1.28–1.64)
	25,000–49,999	0.14	1.25 (1.16–1.35)
Percent Asian[d]	≥ 50,000	−0.01	0.96 (0.68–1.35)
	25,000–49,999	0.12	1.57 (1.35–1.82)
Percent reduced-price or free meals[d]	≥ 50,000	0.21	1.39 (1.21–1.60)
	25,000–49,999	0.10	1.17 (1.09–1.27)
Percent English learners[d]	≥ 50,000	0.26	1.71 (1.48–1.97)
	25,000–49,999	0.18	1.43 (1.31–1.56)
Census 2000 tract-level variables			
Natural log of population density[e]	≥ 50,000	0.43	1.46 (1.29–1.66)
	25,000–49,999	0.73	1.90 (1.72–2.09)
Percent below poverty[d]	≥ 50,000	0.13	1.73 (1.26–2.38)
	25,000–49,999	0.14	1.84 (1.52–2.21)
Percent without high school diploma[d]	≥ 50,000	0.13	1.37 (1.13–1.66)
	25,000–49,999	0.11	1.32 (1.18–1.48)
Percent born abroad[d]	≥ 50,000	0.30	2.52 (2.00–3.17)
	25,000–49,999	0.26	2.23 (1.94–2.56)

[a]AADT is the daily number of vehicles within 150 m of school. [b]Change in the log-odds of traffic category for a one standard deviation increase in the independent variable. [c]Odds of location within 150 m of high traffic (maximum AADT ≥ 50,000) versus low or very low traffic (AADT < 25,000) and odds of location within 150 m of medium traffic (maximum AADT = 25,000–49,999) versus low or very low traffic. [d]ORs and confidence limits for a 25% change. [e]Population density = population (in thousands) per square mile of land in 2000. ORs and confidence limits are given for a one unit change in the natural log of population density.

buildings are located, that offset may be incorrect. The interpolation of points based on address ranges may lead to two potential errors: *a*) if the address range is inaccurate, the point will not represent the true location of an address; *b*) if there is uneven spatial distribution of properties along the block, the interpolation will place the point in the wrong space. This is more of a problem in rural areas because the road segments are longer there. These problems probably did not cause differential misclassification of exposure, however, because we assume a random effect statewide.

Finally, the CalTrans database does not include local roads. However, traffic counts on local roads are relatively small. For example, in San Diego County, traffic volume on local roads was estimated to be 700 vehicles/day (San Diego Association of Governments 2001). Therefore, nearby local roads are unlikely to have a large impact on the concentration of traffic-related pollutants at the school.

Conclusion

Despite the potential limitations, this study describes the distributions of California public schools in relation to busy roads and indicates that large numbers of children may be regularly exposed to elevated levels of traffic-related emissions while at school, and that a disproportionate number of those students are economically disadvantaged and nonwhite. The research exploring associations between exposure to traffic-related emissions and children's health raises the issue of siting new schools with respect to busy roads and mitigating exposures to traffic-related pollutants at existing schools.

Many environmental factors are already considered when siting schools within California, such as proximity to hazardous waste sites and stationary sources of toxic air contaminants. Our results suggest that educators and policy makers, particularly those interested in environmental justice and children's health, should at least consider local traffic emissions as a factor to be considered in school siting decisions. Recently, California introduced legislation, SB 352 Escutia, to prohibit siting new schools within 500 feet (168 m) of a busy road (State of California 2003).

Once schools are located near busy roads, mitigation of exposure may be difficult. Possible measures might include regular maintenance of the heating, ventilation, and air conditioning (HVAC) systems, use of the HVAC system during commute hours in addition to normal use for heating and cooling, use of a filter with good efficiency (e.g., 60–90% efficiency at removal of particles; California Air Resources Board 2003), fixing building air leaks, and avoiding placement of air-intake vents close to busy roads, loading docks, or parking areas. If possible, schools should locate outdoor school activities on a part of the campus farther from the traffic corridor. More important, policy makers must continue their efforts to reduce motor vehicle emissions so that exposures can be mitigated at the source.

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