Roadway Noise, Infant Health and Social Inequality: Evidence from California

Summary Statement

The Biden-Harris administration's investments under the Inflation Reduction Act provide an unprecedented opportunity to address equity and social justice concerns associated with the ubiquitous transportation infrastructure in the United States. We plan to use the BTS National Transportation Noise Maps to estimate the causal impact of ambient roadway noise on the health of infants born to mothers who live close to major roadways, using California (CA) as a case study. With minority and low-income populations being disproportionately located close to major roadways, we will focus on the relationship between ambient roadway noise, infant health and social inequality. We hypothesize that: (i) in utero exposure to ambient roadway noise leads to adverse infant health outcomes such as low birth weight, premature birth and low appearance, pulse, grimace, activity, and respiration (APGAR) scores, and (ii) these health impacts are disproportionately borne by socio-economically marginalized populations and neighborhoods. Our results could bring into focus the need for equitable infrastructure investments in roadway noise abatement strategies such as required noise insulation in new and retrofitted homes and minimum setbacks from major roadways. Such investments would align with the administration's priorities outlined under the Justice40 Initiative.

Research Design and Approach

Motivation and background

According to the Centers for Disease Control, more than 11 million people in the US live within 150 meters of a major highway (Meyer 2013), bearing a disproportionate burden of roadway-related environmental exposure and health risks such as cardiovascular and respiratory disease. Yet, as a non-chemical environmental stressor, roadway noise is often overlooked. In fact, exposure to noise pollution is linked to serious illness and death through increased depression and sleep disturbance, particularly for vulnerable populations including the elderly, children, and pregnant women (Babisch and Kamp 2009; Gehring et al. 2014; Smith et al. 2020; Wen and Khanna 2024). In this project, we focus on the health effects of ambient roadway noise on newborns, a particularly vulnerable segment of the population.

To isolate the impact of noise, we will account for two other pollution sources associated with roadways: traffic-related air pollution and toxic emissions from industrial facilities located close to major roadways. Roadway traffic is a major source of urban and regional air pollution, contributing to concentrations of carbon monoxide, hydrocarbons, nitrogen oxides, particulate matter (PM), and substances known as mobile-source air toxics. In addition, polluting facilities are often located along primary roads, disproportionately affecting communities residing in close proximity. For example, Figures 1-3 show clusters of hazardous facilities along primary roads in New York State (NYS). This combined threat of chemical and non-chemical exposure immediately raises a critical equity concern for nearby communities, often historically disadvantaged and marginalized, who face a disproportionate risk from environmental exposures (Bullard 1983; Banzhaf et al. 2019; Jbaily et al. 2022).

Proposed work and testable hypotheses

We will summarize and synthesize information on noise, air, and toxic pollution near primary roads in CA. Our goal is to describe the association among the three pollutants and isolate the causal impact of roadway noise on the health of infants born to mothers living close to roadways. In doing so, we will identify the communities exposed to this non-chemical environmental threat from the network of roadways in CA and propose potential solutions to mitigate that threat.

Specifically, we will test the following two hypotheses: (i) conditional on local industrial and traffic related air pollution, in utero exposure to roadway noise pollution leads to adverse infant health outcomes such as low birth weight, premature birth, and low APGAR scores, and (ii) these health impacts are disproportionately borne by socio-economically marginalized populations and neighborhoods.

Data

Under a data use agreement with the CA Department of Public Health, the co-PIs have access to the Birth Statistics Master Files (BSMF) and Comprehensive Birth File (CCBF), covering the period from 2015-2021. These data include more than 60 variables describing the circumstances of an infant's health at birth, including the birth parent's gestational and pre-gestational health, lifestyle, and access to gestational and pre-gestational healthcare, birth parents' socio-economic and demographic details, and geographic identifiers for the birth parents' residence(s) at the time of birth for the universe of infants born in CA between 2015 and 2021. We will combine this information with multiple publicly available datasets: 1) roadway noise data from the Bureau of Transportation Statistics (BTS); 2) facility location and emission data from Environmental Protection Agency's Toxic Releases Inventory (TRI); 3) Database of Road Transportation Emissions (DARTE), NASA's satellite data measuring traffic related CO_2 emissions and, if available, spatially detailed vehicular pollution data from the California Air Resources Board (CARB); 4) aggregate demographic and income data from American Community Survey (ACS) combined with 5) the EPA's EJ Screen tool; 6) the USDA's Area and Road Ruggedness Indices; and 7) the National Center for Environmental Information's geo-spatial data on ambient temperature, wind speed and wind direction.

BTS provides data on road noise through the National Transportation Noise Maps for 2016, 2018, 2020 and 2022 which report average annual traffic noise levels across the nation. Using algorithms from the Federal Highway Administration's Traffic Noise Model version 2.5, road noise is generated at receptor locations that are defined as a uniform grid with a resolution of 30 meters and at a height of 1.5 meters above ground. The inputs of the algorithms include average annual daily traffic values, vehicle types, and vehicle speed.[1] Since ambient noise is highly localized, we will utilize the geographic coordinates for each infant's birth mother's residence and calculate the ambient annual roadway noise within a circular buffer of 1 km radius (Wen and Khanna 2024). We may also exploit BTS's Highway Performance Monitoring System which provides information such as the number of lanes on a highway.

We will use toxic emissions data from the TRI that reports the quantities of nearly 800 chemicals and chemical groups released into the air, water, and soil from the chemical, manufacturing, metal mining, and electric power generation sectors, along with the locations of the facilities reporting the data. These chemicals include OSHA classified carcinogens and persistent bio-accumulative toxins as well as dioxin and dioxin-like compounds. Based on facility location, we will calculate the local onsite emission of toxic chemicals in the birth parent's residential neighborhood (such as 5-digit zip code area, census tract and/or census block group) by summing up the total onsite releases from all TRI facilities within each area. For example, in Figures 1-3, we use 2018 onsite releases by facilities located in NYS.

To identify marginalized communities and their location, we plan to use information from EJ Screen and the ACS 5-year estimates. As an illustrative example, Figure 1 shows the 2013-2018 census block group share of racial minorities in NYS.

Empirical strategy

We summarize the reduced form model describing the association between infant health outcomes and roadway noise as follows:

$$\begin{aligned} Outcome_{it} = \; & \alpha_0 + \alpha_1 Roadnoise_{it} + \beta_1 ParentsSocioDemographics_{it} \\ & + \beta_2 MothersHealth\&HealthCareInformation_{it} \\ & + \beta_3 NeighborhoodToxicPollution_{it} + \mu_{it} \end{aligned}$$

where $Outcome_{it}$ refers to the birth outcome (birth weight, gestational age or APGAR score) for infant i born in year t, $Roadnoise_{it}$ measures the annual ambient roadway noise in year t within a buffer of 1km

[1] In Figure 2, we compute the 2018 census block group noise as a simple average of all the 30 m^2 pixels with detectable noise.

radius around the birth mother's residence, $ParentsSocioDemographics_{it}$ is a vector of variables describing the economic, demographic and social circumstances of the infant's birth, $MothersHealth\&HealthCareInformation_{it}$ is a vector describing the birth parent's health status and access to health care during pregnancy and $NeighbordhoodToxicPollution_{it}$ summarizes toxic emissions in the infant's birth mother's residential neighborhood during pregnancy.

There are two main challenges in identifying the causal relationship between ambient roadway noise and the infant health outcomes. The first is the correlation between local traffic-related air pollution and ambient roadway noise; the second arises from residential sorting behavior, due to which ambient roadway noise may not be randomly assigned and is expected to be endogenous to an infant's health.

To disentangle the effect of ambient roadway noise from traffic-related air pollution, we will control for tailpipe emissions using DARTE. DARTE provides data on annual on-road emissions based on roadway-level traffic and state-specific emission factors for multiple vehicle types, and covers the conterminous US from 1980-2017 at a spatial resolution of 1km. Figure 4 shows the 2017 CO_2 emission map for southern CA; areas with more traffic-generated CO_2 emissions (indicated by cells with a deeper red color) tend to be fairly close to highways. Similar to the noise measurement, we will approximate the traffic-related air pollution surrounding a birth parent's residence as the average across all pixels in the 1km buffer that have detectable CO_2 emissions.[2] If possible, we will test the sensitivity of our analysis using spatially detailed air pollution data from CARB. One limitation of DARTE is that it only provides estimates of on-road CO_2 emissions, and lacks estimates of other traffic-related air pollutants. However, Liang et al. (2024) report that traffic-related CO_2 is correlated with other pollutants like SO_2 and NO_X and we will use on-road CO_2 emissions to approximate tailpipe emissions.

We will address the endogeneity of ambient roadway noise and traffic related air pollution through multiple instrumental variables (IVs). The most novel of these are the USDA's Area and Road Ruggedness Indices, which include the Area Terrain Ruggedness Index (ATRI) and the Road Ruggedness Index (RRI). These indices measure topographic variation or "ruggedness" for census tracts in the US. While the ATRI is computed using the sum change in elevation between each grid cell and all 8 neighboring cells, the RRI is based only on the neighboring cells through which a road passes. Since roadway noise is primarily generated through the friction between the vehicle tires and the surface of the road, slower-moving vehicles generate lower noise. Combined with the fact that drivers drive relatively slowly in areas with greater topographic variation, we anticipate that road noise is generally lower in such areas and expect a negative correlation between the ATRI and roadway noise. However, conditional on the ATRI, we anticipate that road noise is higher in areas with a higher RRI because of the more frequent deceleration and acceleration of vehicles (Wen and Khanna 2024). We also anticipate that topography affects local traffic related air pollution since different driving behaviors impact the fuel efficiency of vehicles, which contributes to variation in traffic-generated air pollution. However, conditional on socio-economic factors, we do not expect strong correlation between ATRI/RRI and residential location.

The other key IVs include wind speed and wind direction (see Deryugina et al., 2019; Persico and Marcotte, 2022). Hener (2022) exploits the exogenous change in daily wind speed and wind direction to investigate the effect of aviation noise on local crime rates. Zou (2017) establishes the link between wind farms and suicide rates by investigating how wind direction changes exposure to low-frequency noise.

[2] Wen and Khanna (2024) find that for a sample of approximately 14000 individuals across the US, the correlation between CO_2 emissions reported in DARTE and the ambient noise reported by the BTS noise maps is about 20%. This is likely because of the different physical mechanisms that generate noise (which comes from the friction between the vehicle tires and the surface of the road and drag due to wind resistance) and tailpipe emissions (which are related to fuel efficiency).

However, roadway noise and, likewise, traffic-related air pollution, is not a point source pollutant (unlike, for example, toxic emissions from a TRI facility). Rather we think of them as being generated along "lines" (for example, highways). Instead of emphasizing upwind/downwind directions, we plan to use the number of days with the four prevailing wind directions. To account for local variation in the effect of wind direction on noise and air pollution propagation, we will interact the wind direction variables with county/census tract fixed effects. That is, we will allow the effect of an east wind to differ for a location in Orange County (in southern CA) from that in Alameda County (in northern CA).

The propagation of noise is not only affected by wind but also by ambient temperature. The density of air is lower at higher temperatures which refracts noise away from the ground and reduces ambient noise. We plan to use the average temperature during pregnancy to address the impact of seasonality and the associated variation in the propagation of noise.

Preliminary analysis and findings

In preliminary work, we correlate the three types of roadway related environmental threats -- noise, toxic emissions, and PM -- with socioeconomic characteristics at the block group level using NYS as an example. We find a strong correlation between block groups with a larger share of racial minorities and primary roadways in NYS (Figure 1). At the same time, manufacturing facilities emitting toxic chemicals are also located along these roadways, with the most polluting facilities being located along I-90 and I-87 and their access roads (Figures 1 and 2). In addition, PM concentrations in NYS are also starkly higher in the census tracts near these roadways (Figure 3). Furthermore, the census block groups with the highest traffic noise exposure (i.e., exceeding the EPA's safe limit of 55 dB) are also adjacent to the same primary roadways in NYS (Figure 2).

Research team

The research team comprises of Dr. Neha Khanna (PI, Professor, Binghamton University), Dr. Ruohao Zhang (co-PI, Assistant Professor, Pennsylvania State University) and Dr. Huan Li (co-PI, Assistant Professor, North Carolina A&T State University), assisted by a Ph.D. student at Binghamton University. Dr. Khanna is an expert on US air quality policy, including environmental justice, voluntary self-regulation and pollution spillovers under the Clean Air Act. Dr. Zhang's research focus is environmental and climate justice, environmental impact on public health, and environmental regulation. Dr. Li researches the persistence of environmental exposure and the impact of climate change related natural disasters on social equity and segregation. She is the Director of the Lab for Economic and Environmental Equity at NCAT.

Conflict of Interest Statements

PI Neha Khanna declares that she has no relevant or material financial interests that relate to the research described in this paper.

Co-PI Ruohao Zhang declares that he has no relevant or material financial interests that relate to the research described in this paper.

Co-PI Huan Li declares that she has no relevant or material financial interests that relate to the research described in this paper.

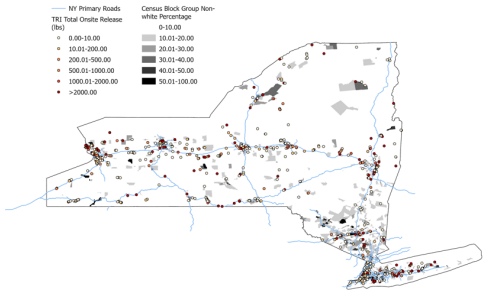


Figure 1: Primary roadways, TRI onsite releases, and census block group minority share (NYS, 2018)

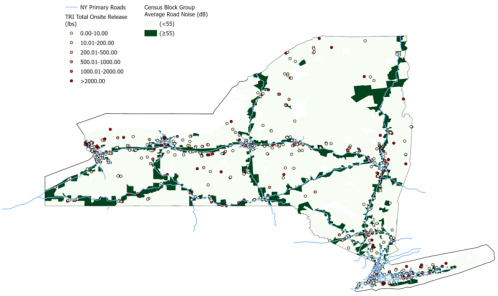


Figure 2: Primary roadways, TRI onsite releases, and roadway noise by census block group (NYS, 2018)

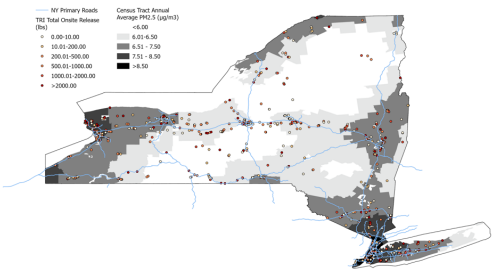


Figure 3: Primary roadways, TRI onsite releases, and census tract $PM_{2.5}$ (NYS, 2018)

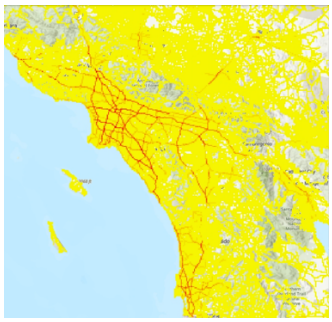


Figure 4: CO_2 traffic emissions in southern CA (2017)

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