

Spatio-Temporal Analysis of the Roadside Transportation-Related Air Quality (StarTraq 2024): Time-Series Analysis

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Introduction

Fresno County, located in the center of California's San Joaquin Valley (SJV), faces some of the most persistent and severe air quality challenges in the United States. Despite the nation's strict auto-emissions standards, Fresno County has ranked among the worst for air quality, with high levels of particulate matter (PM) and ozone (O₃), contributing to asthma, cardiovascular disease, and premature mortality. To address this critical issue, this study asks: How have transportation emissions, roadway infrastructure, and land use changes jointly shaped air quality in Fresno County over the past three decades, and what does this mean for the future? By integrating air monitoring records, mobile emissions data, road network data, and land-use data, the study provides data-driven insights for planners and policymakers focused on multi-decade assessments of air quality improvements to support sustainable transportation and urban development, reshaping the region's environmental trajectory and supporting California communities.

Study Methods

This study built a comprehensive geospatial database integrating air quality, transportation emissions, roadway infrastructure, and land cover data from 1985 through projected 2032 trends.

- **Air Quality Trends (1991–2023):** Ambient concentrations of six criteria air pollutants, PM_{2.5}, PM₁₀, NO₂, SO₂, CO, and O₃, were analyzed using U.S. EPA Air Quality System (AQS) data from monitoring stations across Fresno County. Strict quality controls ensured consistency and completeness. Annual averages were calculated to identify county-level long-term trends.
- **Mobile Source Emissions & Travel Activity (2000–2032):** On-road vehicle emissions and Vehicle

Miles Traveled (VMT) were obtained from the California Air Resources Board's EMFAC 2025 model. Emissions were analyzed by pollutant, fuel type, and 13 umbrella vehicle categories, including passenger vehicles, in-state and out-of-state freight trucks, transit buses, and public fleets. This allowed evaluation of regulatory impacts and projected emissions through 2032.

- **Road Network Analysis (2016–2023):** U.S. TIGER/Line data were used to measure changes in primary highways, secondary roads, and local streets. Road length was aggregated by classification codes to assess infrastructure expansion or stability. Land Cover Change (1985–2023): National Land Cover Database (NLCD) rasters (grid-based land cover maps) were processed to quantify urban expansion, agricultural conversion, forest loss, and changes in vegetative cover. Land classes were grouped by their potential to either contribute to pollution or help absorb it. The data integration enabled a holistic, long-term analysis of transportation-related air pollution in Fresno County.

Findings

- Air quality has improved significantly, but not evenly: Between 1991 and 2023, PM_{2.5} fell by more than 50%, PM₁₀ declined by roughly 50%, and NO₂ dropped by over 60%. SO₂ emissions nearly disappeared after ultra-low sulfur fuel regulations. These pollutants affect human health in different ways, particularly respiratory and cardiovascular health. Carbon monoxide declined by more than 60%. These reductions reflect decades of aggressive California vehicle and fuel standards. However, ozone remains persistent

due to complex photochemical formation and climate influences (chemical reactions between pollutants in sunlight).

Diesel exhaust once dominated Fresno's air pollution. Today, brake and tire wear from everyday passenger vehicles represents the largest remaining source of roadway particulate matter.

- Freight emissions have reduced, but passenger vehicles now dominate: Heavy-duty diesel trucks were historically the largest contributors to $PM_{2.5}$ and NO_x . Since 2000, diesel particulate emissions have fallen by nearly 90%, and NO_x by up to 98%, due to fleet turnover and stricter regulations. By contrast, passenger vehicles, because of their overwhelming Vehicle Miles Traveled, now represent the largest share of remaining emissions for several pollutants.
- A major shift from exhaust to friction: As tailpipe emissions declined, brake and tire wear particles became the dominant source of PM_{10} by 2017 and $PM_{2.5}$ by 2023. This marks a structural change in air pollution management.
- Urban growth is reshaping environmental conditions: Over 130 km² of land, primarily agricultural, has been converted to urban development since 1985. Meanwhile, evergreen forests in the Sierra Nevada portion of the county declined by over 700 km² due to drought and wildfire.
- Carbon emissions remain stubborn: Despite progress on criteria air pollutants, CO₂ emissions remain closely tied to VMT and passenger travel demand. Technological improvements have not yet fully decoupled greenhouse gases from mobility growth.

Policy/Practice Recommendations

1. Shift focus from engines to activity: Future air quality improvements require reducing total vehicle miles traveled (VMT), not just improving

engine emissions. Land-use planning should prioritize transit-oriented growth and multimodal access.

2. Address non-exhaust emissions: Brake and tire wear now dominate particulate emissions. Policymakers should consider material innovations, dust mitigation strategies, and expanded transit investment.
3. Electrification and greenhouse gases: While electric vehicles reduce tailpipe emissions, further reductions in CO₂ and NO_x should also be considered.
4. Integrate land use and air quality planning: Urban expansion and vegetation loss affect pollution mitigation. Coordinated planning can protect green space and reduce environmental health disparities.

Fresno's next air quality challenge is no longer just cleaner engines. It is smarter growth and transportation demand management.

About the Authors

Dr. Kwon is an environmental health researcher who focuses on assessing traffic emissions and their adverse health effects. Dr. Ahn is a geomatics engineering researcher who focuses on geospatial analyses of sustainable infrastructure systems, integrating environmental and geographic factors. Dr. Chung's research examines time-series analysis on transportation systems and data-driven approaches to improving environmental equity and urban sustainability.

To Learn More

For more details about the study, download the full report at <https://transweb.sjsu.edu/research/2444>



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