Transportation-related air pollution and energy problems are a significant issue in the U.S. and across the world. Transportation's voracious appetite for petroleum fuels not only makes the U.S. highly dependent on foreign sources of energy, but also contributes significantly to a variety of environmental problems, especially air pollution, including greenhouse gases (GHG) that drive global climate change and toxic air pollutants that put the health of more than 146 million U.S. residents at stake. The current situation, already an enormous challenge, is dwarfed when compared to the forecast for a future fundamental clash: a 100 million increase in population could double the demand for passenger travel by 2040, not to mention the even faster growth of freight transportation that will be doubled by 2025 due to expanded international trade. Such energy and environment challenges of transportation is even more extraordinary in developing countries such as India and China, where swift economic development is bringing more cars to more households (of a ten times larger population base than the U.S.), ever-increasing freight trucks onto extending roads, and escalating emissions into the worsening air. The World Health Organization estimates that urban air pollution causes 200,000 deaths per year worldwide and that it will be responsible for 8 million premature deaths from 2000 to 2020. Sacrificing transportation needs for environmental quality is simply infeasible since transportation provides a vital wheel for economic development. Instead, “environmental and economic goals need to be viewed as collaborative efforts,” according to Christine Whitman, former administrator of the US EPA, “because they can create a powerful win-win partnership.”

How do we meet the transportation needs in the age of development without sacrificing environment and energy sustainability? The relationships between transportation and environment/energy systems are extremely complicated. An organically integrated transportation and environment/energy systems approach is necessary and most appropriate to analyze the critical linkages between the systems, because transportation and environment/energy problems, whether they involve planning, design, or operational issues, are often characterized by conflicting and competing objectives, economic and environmental constraints, and complex physical and social/political processes.

Gao’s research and teaching focus on the nexus of transportation and environment/energy systems. The overarching goal of his research predicates on a multi-disciplinary system-driven

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1 Sustainability in the age of development has been identified by Cornell Faculty as a strategic opportunity for the University to publicly demonstrate its expertise and leadership capabilities.
approach to education and novel basic research, applied research and implementation discoveries that will advance the understanding of the transportation-air quality-energy nexuses, where the lack of science and knowledge is the biggest barrier to successful transportation, air quality and energy management strategies. Specifically, his recent research studies the following areas:

1. Temporal and spatial statistical analyses of tropospheric ozone, nitrogen oxides (NOx) dynamics and heavy-duty truck transportation activities;
2. Clean-up of the legacy diesel fleet—mathematical modeling in search for cost-effective environment abatement strategies;
3. On-board measurement and modeling of diesel particle number emissions from alternative vehicle/energy technologies;
4. Real-time measurement and modeling of travelers’ exposure to fine particles in New York City and on road networks in NYS;
5. Green house gas (GHG) emissions reduction from the transportation sector. Diversification in the driveway: mean-variance optimization for greenhouse gas emissions reduction from the next generation of vehicles;
6. Biofuels in the United States: 1) assessing the potential for biomass-to-liquids fuel production using existing sustainable forest resources; and 2) environmental impacts of biofuels (e.g., emissions measurement and modeling of vehicles burning biofuels)
7. Equity and environmental justice in the clean air school bus program.

As a core part of the talk, we’ll look into the ozone weekend effect (OWE). Successful ozone control strategies require an improved understanding of transportation emission activities and ozone formation/scavenging dynamics, which are reflected in the variability associated with diurnal ozone cycles. This study contributes to our understanding of ozone dynamics by conducting functional data analysis (FDA) of daily ozone and NOx curves. Functional analysis of variance (FANOVA) is used to statistically examine day of week effects on ozone/NOx cycles, particularly the ozone weekend effect (OWE). The OWE is then directly linked to identifying efficient ozone control strategies by statistically examining weekly patterns in the timing, magnitude and fleet mix of traffic activities, the dominant sources to ozone precursors emissions. We conduct nonparametric factorial analyses of light-duty vehicle (LDV) and heavy-duty truck (HDT) volumes observed at 27 weigh-in-motion (WIM) traffic monitoring stations in southern CA to examine the implications of their weekly and spatial patterns for the OWE. The results indicate statistically significant variations in daily total as well period-based traffic volumes by day of week, vehicle group (LDV vs. HDT) and WIM locale with respect to LA metro. These statistically tested weekly patterns in traffic, translated into weekly variations in running exhaust emissions, support five of seven California Air Resource Board’s OWE hypotheses: NOx-Reduction, NOx-timing, carryover near the ground, aerosol and UV radiation and ozone quenching hypotheses. The results of this research will significantly help in the development of State Implementation Plans (SIP), the evaluation of traffic control measures (TCMs), and the modeling of interactions between transportation and environment systems.