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Uncovering Traffic Emissions: Converging Direct Measurements and Mobility Science

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Issue

Despite the years of climate change mitigation effort, per capita transportation emissions are on the rise. Reducing vehicle miles traveled, congestion mitigation and increasing vehicle efficiency are three strategies to reduce CO_2 emissions from vehicles. Outcomes of these strategies may contradict each other considering their impacts on the road network and possible behavior changes within the transportation system. Though, models used in policy evaluations do not capture the interplay between vehicle characteristics, travel demand, and urban form. Understanding the spatial and temporal variations in vehicular emissions and the impact of each subsector requires collaboration between two seemingly separate fields: emissions modeling and urban science.

Our research combines state-of-the-art methods from urban science and atmospheric chemistry to develop a Mobile Data Emission System (MODES), which is a portable framework for making fine-grained vehicle emissions estimates using a large sample of mobile phone data for the Bay Area[1], Location Based Service Data from SafeGraph[2], and Uber Movement Speeds data[3]. The MODES results were validated with two different sensor-based emission estimates, including the direct CO_2 measurements of the Berkeley Air quality and CO_2 Network (BEACO2N).[4]

Key Research Findings

Actual vehicle efficiency can vary from that reported by vehicle manufacturers by 17% on average depending on road conditions. The fuel consumption of all the routes in our study was calculated for different manufacturer-reported fuel economies with the calibrated StreetSmart model.[5] The variation in real fuel economy for some vehicle models was as high as 70%. Our results also show that median fuel efficiency for trips during the state's COVID-19 stay-in-place (SIP) orders were 6-7% higher than before the first SIP order. This can be explained by less congestion on the roads.

High density areas are characterized by low per person travel mileage and increased congestion. We grouped Bay Area cities into four categories based on population density and per person travel mileage. Through our analysis, we observed that high population density is associated with low travel mileage per person but in low population density areas mileage per person varies.

Vehicle mileage is the main contributor to vehicular emissions. Emission efficiency of a trip and varies greatly between different cities. The mean emission efficiency of the cities in our study was 209 CO_2/km and the values ranged between 175 to 225 CO_2/km. The difference between the cities arises from the congestion level experienced and the amount of stop and go traffic.

Congestion affects vehicular emissions exponentially, yet its impact is less compared to travel mileage. At the same congestion level, emissions for a trip can vary significantly due to mileage; 90% of the trips lie within the dotted lines. The trips outside this region are short in distance and have much longer idling times per mile traveled.

Conclusion

MODES, a data-driven framework for estimating vehicle emissions from mobile phone data, is able to quantify the relationship between vehicular emissions, congestion, and miles traveled using accessible metrics. The TomTom Traffic Index[6] provides live and historical congestion values. Vehicle mileage is approximated by vehicle sensor counts, fuel sales, or surveys, and vehicle registration data provides insights on the manufacturing fuel economy of the vehicles used in a city.

Using individual mobility data allows researchers to relate emissions produced across the transportation network to the home locations of travelers. This provides valuable insights into sustainable urban forms that local emission measurements cannot provide.

More Information

This policy brief is drawn from the published article "Scaling of Traffic Emissions by Converging Direct Measurements and Mobility Science" prepared by Ayse Tugba Ozturk and Marta C. Gonzalez with the University of California, Berkeley. The report can be found at: https://humnetlab.berkeley.edu/index.php/publications/. For more information, contact Marta Gonzalez at martag@berkeley.edu.

[1]Xu, Yanyan, Colak, Serdar, Kara, Emre C., Moura, Scott J., and Gonzalez, Marta C., *Planning for electric vehicle needs by coupling charging profiles with urban mobility*, Nature Energy **3**, 484 (2018).

[2]https://docs.safegraph.com/docs/neighborhood-patterns

[3]https://movement.uber.com/

[4]Fitzmaurice, H., Turner, A. J., and Kim, J., Chan, K., Delaria, E. R., Newman, C., Wooldridge, P., and Cohen, R. C., *Assessing vehicle fuel efficiency using a dense network of CO2 observations*, Atmospheric Chemistry and Physics Discussions **1**, (2021).

[5]Oehlerking, A. L. *StreetSmart: modeling vehicle fuel consumption with mobile phone sensor data through a participatory sensing framework*. Ph.D. thesis, Massachusetts Institute of Technology. Dept. of Mechanical Engineering. (2011).

[6]Tomtom traffic index. https://www.tomtom.com/traffic-index/. Accessed: 2022-11-07.

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