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Evaluating health outcomes from vehicle emissions exposure in the long range regional transportation planning process

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ABSTRACT

The air quality impacts of a metropolitan region's long range transportation plans are generally evaluated by estimating the change in a region's vehicle emission inventory. A change in the overall quantity of vehicle emissions in a region is generally associated with lower concentrations of vehicle related air pollutants and therefore a reduction in public health risks from exposure to vehicle emissions. A major limitation of this common approach is that aggregate emission inventories provide no information about localized impacts. While some areas experience air quality improvements, air quality can become worse in others. Such aggregate analyses are ill suited for addressing contemporary transportation planning questions such as identifying vehicle emission exposure hotspots, quantifying health risks, and evaluating environmental justice concerns. In this paper we describe a computationally efficient analysis framework for evaluating a regional transportation plan with spatially detailed estimates of vehicle emission exposures and related health outcomes. We then apply our framework in a case study of fine particulate matter exposure in the Atlanta, Georgia metropolitan area and the changes expected to occur through the year 2040 under the region's long range transportation plan. We find that exposure and health risks decline from current levels by 2020 but then begin to slowly increase in some areas by 2040. We also find that low income and minority populations have the greatest health risks, confirming environmental justice concerns that have been noted in other regions.

1. Introduction

A large body of evidence links fine particulate matter ($PM_{2.5}$) exposure with a wide range of negative health outcomes including cardiopulmonary mortality (Boldo et al., 2006; Krewski et al., 2009; Pope et al., 1995), ischemic heart disease mortality (Krewski et al., 2009; Laden et al., 2000; Pope and Dockery, 2006), lung cancer mortality (Krewski et al., 2009; Pope et al., 2002; Pope et al., 2011), and infant mortality (Woodruff et al., 1997). Prior research also finds that the concentrations of many vehicle emissions, including $PM_{2.5}$, are elevated along roadways (Karner et al., 2010; Zhou and Levy, 2007) and that up to 30% of an individual's exposure to particulate matter in urban areas may come from mobile sources (Boudet et al., 2000). Furthermore, exposure to $PM_{2.5}$ from vehicle exhaust has been linked to a broad range of negative health outcomes (Allen et al., 2009; Brugge et al., 2007; Gan et al., 2010; Garshick et al., 2004; Gauderman et al., 2007; Health Effects Institute, 2010; McConnell et al., 2006; Peters et al., 2004; Suglia et al., 2008; Wilhelm and Ritz, 2003). Reducing exposure to $PM_{2.5}$ from vehicle exhaust emissions is therefore an important public health goal.

Identifying populations at risk from exposure to vehicle exhaust and developing effective plans and policies to abate emissions

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and mitigate exposure, however, is challenging because vehicle exhaust emissions are unevenly distributed across urban areas. Furthermore, the uneven distribution of vehicle exhaust emissions often raises environmental justice concerns. Minority and low income populations are more likely to live near high volume roads where the concentration of vehicle exhaust emissions are elevated (Apelberg et al., 2005; Buzzelli and Jerrett, 2007; Chakraborty et al., 1999; Jephcote and Chen, 2012; Kingham et al., 2007; Rowangould, 2013, Rowangould, 2015).

Over the past several decades, broad measures have been implemented to reduce health impacts linked to vehicle emissions exposure. The United States Department of Transportation requires Metropolitan Planning Organizations (MPOs) to create long range regional transportation plans for urban areas with 50,000 or more residents. However, requirements for evaluating how these long range plans may affect air quality, exposure and public health are very limited. The Clean Air Act requires the US Environmental Protection Agency (US EPA) to set National Ambient Air Quality Standards (NAAQS) for six criteria air pollutants, including $PM_{2.5}$, at levels that will protect public health. US EPA regulations only require those MPOs located in areas violating the NAAQS (i.e., non-attainment areas) to perform an air quality assessment of their transportation plans. Even then, transportation conformity regulations only require that MPOs simply estimate regional emission inventories and ensure that they fall below emission budgets prescribed in an approved State Implementation Plan. There is no spatial detail, no assessment of how exposure to emissions changes, no assessment of the change in health risk and no consideration of environmental justice concerns.

While MPOs, regardless of their NAAQS attainment status, tend to voluntarily incorporate improved air quality and health as specific objectives in their planning processes (Handy, 2008), the measurement of these objectives is typically limited to a qualitative review of the plan. For example, a study by Lyons et al. (2012) evaluated the activities of four MPOs that were considered leaders in integrating health and transportation in to their planning processes (Nashville Area MPO; Puget Sound Region Council; Sacramento Area Council of Governments; and San Diego Association of Governments). The study indicates none of these MPOs estimated changes in exposure to vehicle emissions and their potential health impacts in the development of their long range transportation plans. We followed up and reviewed the most recent long range transportation plans developed by the same four MPOs and find that this is still the case today.

While quantitative exposure and health risk assessments are not being implemented at the regional transportation planning level, they do occur at the individual project level. For example, the change in $PM_{2.5}$ exposure and associated health impacts were evaluated for the proposed development of the MacArthur BART Transit Village Project in Oakland CA (UC Berkeley Health Impact Group, 2007). A line source dispersion model (CAL3QHCR Version 2.0) was used to model how exposure to $PM_{2.5}$ emissions from vehicle traffic would change once the project was developed. The authors found that project related traffic would increase average $PM_{2.5}$ concentrations by 0.30 $\mu g/m^3$. The study then translated this into 2.7 additional deaths in a population of 100,000. Similar, project level, assessments are not uncommon and are often carried out as part of US EPA required hotspot analysis in non-attainment areas or when an Environmental Assessment or Environmental Impact Statement is required under the National Environmental Policy Act (NEPA).

Project level exposure assessments may also be required by policy. For example, in 2008, the City and County of San Francisco adopted an ordinance on roadway proximity health effects that requires modeling the concentration of $PM_{2.5}$ (as a measure of traffic pollutants) when projects are built near busy roadways. If modeled levels of traffic related $PM_{2.5}$ exceeds 0.2 $\mu g/m^3$, then the developers are required to incorporate ventilation systems that remove at least 80 percent of $PM_{2.5}$ from outdoor air. (San Francisco Health Code, Article 38 - Air Quality Assessment and Ventilation Requirement for Urban Infill Residential Development, Ord. 281-08, File No. 080934, December 5, 2008).

Project level exposure and health risk assessments may identify potential health risks, but at this late stage in a project's development if significant risks are identified mitigation measure are relatively limited. For example, San Francisco's air quality ordinance requires filtration of a building's air to remove high pollutant concentrations but does not consider or require abatement of emissions. Evaluating vehicle emissions exposure and health risks during the long range regional transportation planning process could provide information for creating potentially more effective and efficient emission abatement and exposure mitigation strategies. For example, strategies such as a greater investment in regional transit systems or revising land-use policies to incorporate smart growth principles that encourage less vehicle use could be evaluated and their effect on exposure hotspots and disadvantaged communities could be identified. These types of regional strategies, however effective and efficient they may be, are generally not considered within the scope of a project subject to project level environmental analysis, such as that required by the National Environmental Policy Act.

Prior studies demonstrate a variety of methods for integrating regional travel demand, vehicle emission and atmospheric dispersion or chemical transport models to estimate the concentration of vehicle emissions across urban areas and exposure to them. For example, several studies have advanced methods for integrating models to develop more spatially detailed regional vehicle emission concentration and exposure estimates (Beckx et al., 2009b; Cook et al., 2008; Lefebvre et al., 2011; Rowangould, 2015). Several similar studies evaluate how the movement of a region's population throughout a day affects exposure estimates from these integrated models (Beckx et al., 2009a; Dhondt et al., 2012; Hatzopoulou and Miller, 2010; Shekarrizfard et al., 2016) including time spent in different micro environments (Vallamsundar et al., 2016). Furthermore, Dhondt et al. (2012) use an integrated modeling approach to estimate vehicle emission exposure for each municipality in Flanders, Belgium and then apply health impact functions to estimate health risk from their exposure estimates. The primary aim of the study by Dhondt et al. (2012) is evaluating how risk estimates differ when the movement of the population is accounted for.

While the above cited studies demonstrate the technical capacity to evaluate how regional transportation systems affect local air quality and health risks, these methods have not been applied to the analysis of regional transportation plans. Prior studies have focused on the development, demonstration and evaluation of methods, typically using current or a previous year's travel data. In this

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