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Traffic exposure near the Los Angeles–Long Beach port complex: using GPS-enhanced tracking to assess the implications of unreported travel and locations

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ABSTRACT

Traffic exposure assessments could misclassify the extent and locations of exposure if traditional recall surveys and self-reported travel diaries do not record all participant activities. The Harbor Communities Time Location Study (HCTLS) examines the nature, extent and implications of underreported locations/trips in a case study which used portable Global Positioning Systems (GPS) devices to track the diurnal patterns and traffic exposure of 47 residents of communities near the Los Angeles–Long Beach port complex. Participants were similar to adults nationwide in time spent indoors, in-vehicle, and outdoors, but spent more time indoors at home (78% vs. 66%). Overall, participants did not report nearly half (49%) of the locations and trips identified in GPS-enhanced data on their activity diaries, resulting in about 3 h/day in unreported locations and 0.6 h/day in unreported trips. The probability of a location/trip being underreported was systematically correlated with participant and location/trip characteristics. Self-reported data missed about 50 min of heightened air pollution exposures during the 5 h/day on average participants spent in high-traffic areas and about 30 min during the 4 h/day near truck routes. GPS-enhanced methods provide opportunities to more precisely characterize exposure periods and tools to identify facility, roadway, and land use types of the greatest concern for mitigation efforts.

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1. Introduction

Human environmental exposures are directly related to location and travel patterns over the day (Ott, 1985) and not accounting for air pollution concentrations at locations such as workplaces and schools and in transportation microenvironments could result in exposure misclassifications and inadequate policy and planning remedies (Beckx et al., 2009). Traditional exposure assessment methods account for location and travel patterns based on recall activity surveys and self-reported activity and trip diaries (Klepeis et al., 2001; Marshall et al., 2006), but these data are often incomplete since respondents tend to not report all locations and trips (Bricka and Bhat, 2006; California Department of Transportation, 2002). Incomplete activity profiles could result in air pollution exposure misclassification given that gaps in location and travel information can be extensive and systematically correlated with individual and household characteristics and location and trip characteristics (Bricka and Bhat, 2006).

The Harbor Communities Time Location Study (HCTLS) examines the implications of underreported locations and trips on exposure classification in a case study in which portable Global Positioning Systems (GPS) devices were used to track 47 residents of communities adjacent to the Ports of Los Angeles and Long Beach in everyday activities. We developed a GPS-enhanced time-activity database for participants by using GPS data to validate participant-reported time-activities for 2–3 days, identifying locations and trips participants did not report, and completing activity and microenvironment profiles in follow-up interviews. We begin this article by reviewing the literature and providing an overview of our study design and methodology. Our analysis starts by profiling the time-location patterns of HCTLS participants and comparing these patterns to those of respondents to the National Human Activity Pattern Survey (NHAPS) in order to understand whether our non-random sample spent a disproportionate amount of time at or near their residence in port-adjacent communities which are heavily impacted by nearby port, goods movement, and refinery operations (Hricko, 2008; Kozawa et al., 2009). Next we examine the rate at which participants underreported locations and travel in their activity diaries and identify the individual, household and trip characteristics associated with underreported patterns. We then use proximity-based measures to examine the implications of participant diurnal location patterns on their exposure to heavily-traveled roadways and truck

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routes, and the extent to which underreported locations and travel could result in misclassifications of traffic exposure. We conclude by discussing insights from our HCTLS case study which enhance our understanding of how dynamic exposure assessment methodologies can more precisely identify environmental exposures compared to traditional approaches, can help resolve exposure misclassifications for underreported locations and trips, and can strengthen policy and urban planning strategies to mitigate air pollution exposures.

2. Background

2.1. Traffic exposure in goods movement corridors

Vehicle-related air pollutants are highly localized during the day within approximately 200–300 m downwind of major roadways (Zhu et al., 2002) and residential proximity to major roadways and heavy-duty diesel truck (HDDT) routes has been associated with adverse health impacts including asthma prevalence, reduced lung function, and mortality (Lipfert and Wyzga, 2008; McConnell et al., 2006; Perez et al., 2009). Disadvantaged communities tend to experience heightened levels of traffic exposure and low-income and minority communities in southern California disproportionately reside in high-traffic areas and may experience heightened exposure to vehicle-related pollutants (Houston et al., 2004). Environmental justice concerns are heightened in goods movement corridors in which substantial volumes of HDDTs transport shipping containers on arterials near residences and sensitive uses (Houston et al., 2008; Hricko, 2008; Perez et al., 2009), a pattern which results in elevated near-roadway concentrations of diesel exhaust particulate matter, a toxic air contaminant (California Air Resources Board, 2008; Kozawa et al., 2009).

Location-specific methods have been used to assess the potential magnitude of near-roadway pollution impacts and their environmental justice implications for populations in residential (Gunier et al., 2003; Houston et al., 2004), school (Appatova et al., 2008; Green et al., 2004), and childcare locations (Houston et al., 2006), but fail to evaluate the impact of individual time activity on diurnal traffic exposure. Concentrations of vehicle-related pollution in indoor, in-transit, and outdoor microenvironments can vary substantially (Fruin et al., 2008; Kozawa et al., 2009; Zhu et al., 2002, 2005), and linking time-location information with pollution proximity measures provides a valuable tool for estimating personal exposure and identifying where traffic exposures occur over the course of the day (Klepeis et al., 2001; Ott, 1985).

2.2. Methods for assessing activity patterns

Conventional time-location studies generate activity profiles for large samples using recall interviews or diaries, but these studies are associated with concerns about recall, reliability, and compliance and do not capture detailed temporal–spatial data that can be matched to immediate environmental hazards (Klepeis et al., 2001). Several regional travel surveys have tracked travel activities by equipping passenger vehicles with Global Positioning Systems (GPS) devices (Bricka and Bhat, 2006; Murakami and Wagner, 1999) and recent cohort studies demonstrate that portable GPS loggers and GPS-enabled cell phones are valuable tools for monitoring subject locations in exposure studies and can lessen respondent reporting burden and enable data collection over longer periods (Elgethun et al., 2007; Phillips et al., 2001). GPS location tracking can also enhance traditional methods by providing a nearly continuous location database and highly-resolved enhanced insights into the environmental exposures associated with health outcomes across 'activity spaces' occupied over the course of the day (Chen and McKnight, 2007; Kwan, 2004; Millward and Spinney, 2011).

GPS data can be used to validate self-reported time-activities, identify activities that participants did not self-report, and provide the basis for follow-up interviews to verify activity patterns and microenvironment characteristics (Bachu et al., 2001; Flamm, 2007). It has been used to supplement over ten state and regional travel surveys to identify the rates and characteristics of underreported trips and respondents who underreport, and to develop "correction factors" for adjustment of trip estimates for travel models (Bricka and Bhat, 2006; Wolf et al., 2003). Results indicate a wide range in the rate of underreported vehicle trips (10–81%) and that this rate was associated with driver, household and trip characteristics (Bricka and Bhat, 2006; California Department of Transportation, 2002). The rate was about 35% for a 2000/2001 travel survey in southern California. Drivers who were in low-income households, in households with more vehicles, were under 25 years of age, had lower educational attainment, or were unemployed tended to have higher rates of underreported trips; shorter trips (under 5 min) and trips for discretionary purposes were more often underreported and the total number of daily trips was associated with higher trip underreporting (Bricka and Bhat, 2006). Non-reported trips and locations in traditional surveys could potentially result in a sizeable underestimation or misclassification of environmental exposures and time spent in microenvironments. For instance, Wolf et al. (2003) estimated that trips identified by GPS tracking that were not reported in travel surveys in four California counties were associated with a 40% underestimation of associated vehicle miles traveled.

3. Methods

3.1. Study design and area

The HCTLS population was a nonrandom sample of adult residents (21–65 years old) in the Wilmington area of the City of Los Angeles, California and the western portion of the City of Long Beach, California (Fig. 1a). These communities are immediately adjacent to the Ports of Los Angeles and Long Beach, are predominately comprised of low-income and Hispanic residents, and are heavily impacted by nearby port, goods movement, and refinery operations (Houston et al., 2008; Hricko, 2008; Kozawa et al., 2009). The ports of Los Angeles/Long Beach combined are the largest port complex in the United States, carry over 40% of country's imports, and are a major economic "engine" which generates substantial jobs, income and tax revenue (Hricko, 2008; Perez et al., 2009). Despite these benefits, the complex comprises the largest air pollution source in the region and emissions from associated ships, yard equipment, railroads and trucks account for about a quarter of nitrogen oxides, about three quarters of the daily sulfur oxides, and about one tenth of the daily particulate matter in the Los Angeles air basin (South Coast Air Quality Management District, 2007). Air pollution associated with port and goods movement activities in California have been associated with as many as 2400 premature heart-related deaths, over 60,000 cases of asthma symptoms, and more than one million respiratory-related school absences every year (California Air Resources Board, 2006; Lee et al., 2010). HDDTs are of particular concern since they emit high levels of particulate matter (PM) and a complex mixture of gas pollutants with high health risks. Our previous models suggest that local traffic near the port complex contributes almost a fourth of total particulate matter less than 2.5 μm in aerodynamic diameter ($PM_{2.5}$) in near-port communities and that HDDT traffic contributes significantly to the overall fine particulate concentrations in near-port communities (Wu et al., 2009). Fig. 1b presents our