Transportation Research Part D 35 (2015) 11–22

Contents lists available at ScienceDirect

Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd

Simulating the air quality impacts of traffic calming schemes in a dense urban neighborhood

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ARTICLE INFO

Keywords:
Traffic calming
Emission modeling
Air quality
OSPM
Traffic simulation
MOVES

ABSTRACT

In this study, the effects of isolated traffic calming measures and area-wide calming schemes on air quality in a dense neighborhood were estimated using a combination of microscopic traffic simulation, emission, and dispersion modeling. Results indicated that traffic calming measures did not have as large an effect on nitrogen dioxide (NO_2) concentrations as the effect observed on nitrogen oxide (NO_x) emissions. Changes in emissions resulted in highly disproportional changes in pollutant levels due to daily meteorological conditions, road geometry and orientation with respect to the wind. Average NO_2 levels increased between 0.1% and 10% with respect to the base-case while changes in NO_x emissions varied between 5% and 160%. Moreover, higher wind speeds decreased NO_2 concentrations on both sides of the roadway. Among the traffic calming measures, speed bumps produced the highest increases in NO_2 levels.

Introduction

Traffic calming is often used as a means to improve traffic safety by slowing down traffic and minimizing aggressive driving behavior. Traffic calming goals include reducing conflicting movements, pedestrian exposure to traffic, and vehicle speeds, as well as improving visibility, and sharpening drivers' attention. A number of studies have been conducted to evaluate the effects of different calming measures on road safety (Retting et al., 2001; Mountain et al., 2005; Tester et al., 2004; Stout et al., 2006; Grundy et al., 2009; Chen et al., 2013; Grana et al., 2010; Catharinus and van Langevelde, 2011).

Although the safety benefits of traffic calming have been studied in depth, relatively few studies have captured its effects on traffic emissions and air quality. Since most traffic calming measures result in driving at lower speeds causing more frequent accelerations and decelerations, they tend to increase the emissions of vehicles going through calmed zones (Várhelyi, 2001; Ahn and Rakha, 2009), this in turn can potentially affect near-road air quality.

Near-road air pollution affects all users of the street including those who live or perform daily activities along busy roads. Studies have established that exposure to air pollution during commuting constitutes a significant portion of daily personal exposure (de Nazelle et al., 2012; Dons et al., 2012). Research that investigates the interactions between the built environment, active transportation, and air quality has focused on monitoring personal exposure in transport micro-environments, showing air pollution exposure to be elevated not only for pedestrians and cyclists but also for drivers and transit riders

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http://dx.doi.org/10.1016/j.trd.2014.11.014

(Kaur and Nieuwenhuijsen, 2009). Numerous studies have documented the association between traffic-related air pollution and health (Pope et al., 2002; Weichenthal et al., 2011).

Among near road air quality research, few studies have focused on measuring the effects of traffic calming schemes on ambient air quality. Owen (2005) evaluated the effects of traffic calming measures on vehicle emissions and ambient air quality of six small 32 km/h zones in North-West England before and after their installation. Ambient concentrations of nitrogen dioxide (NO_2) and benzene were measured and the authors observed insignificant effects on local air quality in the six zones. Boulter et al. (2001) studied the impact of different traffic calming schemes such as flat-top road humps, round-top road humps, curb extensions, and mini-roundabouts on air quality using a dispersion model. Although their results showed substantial increases in emission rates, the deterioration of local air quality was small with a maximum percentage change of 5% in NO_2 levels. Finally, Cloke et al. (1999) evaluated the effects of implementing area-wide traffic calming measures on NO_2 levels in the Leigh Park area of Havant, England by monitoring NO_2 levels at 6 different sites and showed that the installation of area-wide traffic calming did not have a significant effect on air quality. Oduyemi and Davidson (1998) investigated the effects of several traffic management measures including the traffic restrictions in Dundee city centre, UK on ambient air quality. Diffusion tubes, measuring NO_2 at each site, were used in order to investigate the difference between the air quality within and outside traffic restricted areas.

Despite the limited number of studies that have investigated the effects of traffic calming on air quality, all studies we reviewed pointed to the fact that traffic calming was not associated with significant air quality deteriorations at the local level. These observations however, were highly tied to the range of methods adopted and most importantly the geometry/layout of the corridors or neighborhoods selected.

In a previous study conducted by us, we observed that speed variations while driving on a calmed road with different types of traffic calming schemes, both isolated and area-wide measures resulted in significant increases in vehicle-induced emissions (Ghafghazi and Hatzopoulou, 2014). As an extension of our previous work, the aim of this paper is to (1) illustrate the importance of conducting air dispersion modeling rather than inferring potential air quality effects from changes in emissions solely and (2) quantify the effects of different types of traffic calming measures on near-road air quality. Our study is set in Montréal, Canada where the effects of traffic calming measures currently under consideration in a dense urban neighborhood are quantified from traffic, emissions, and air quality perspectives. We simulated the effects of calming measures on traffic volumes and vehicle drive-cycles both at the sites that underwent the changes and on the wider network. Our neighborhood is compact and dense with road configurations that are prone to trapping and recirculating air pollutants within street canyons. The potential of altering vehicle drive-cycles through traffic calming and in-turn deteriorating near-road air quality may be significant.

Methodology

We investigated the effects of different traffic calming measures on air quality in a Montréal neighborhood using a combination of traffic simulation, emission modeling, and dispersion modeling. We evaluated these effects both at locations that underwent calming measures and on the rest of the network while examining a range of meteorological conditions. First, at the mesoscopic level, we allocated trips on the metropolitan road network in order to derive a demand matrix for the selected neighborhood undergoing traffic microsimulation. Second, at the microscopic level, a traffic simulation model operating in Dynamic Traffic Assignment (DTA) mode was set-up to use the generated Origin–Destination (OD) matrices from the regional model and simulate traffic in the selected neighborhood. Based on the output of the traffic simulation model, we extracted second-by-second speed profiles on a link basis. Third, we employed the USEPA's Motor Vehicle Emissions Simulator (MOVES) to estimate traffic emissions before and after the implementation of traffic calming measures. Finally, using the Danish Operational Street Pollution Model (OSPM), we modeled concentrations of air pollutants along each corridor that underwent traffic calming. Fig. 1 illustrates the interactions between the modeling components.

Study area and traffic calming scenarios

Our study area is set in the Plateau-Mont-Royal borough (also referred to as "the Plateau") within the Montréal metropolitan area. The Plateau has a recorded population of 101,054 individuals in an area of only 8.1 km^2. Its residents are currently experiencing large volumes of "through traffic" due to the borough's proximity to the Montréal central business district leading to the generation of significant amounts of traffic emissions as well as posing safety risks along residential roads. The local council is actively pursuing the goal of managing increasing traffic volumes especially on local streets and improving pedestrians' and cyclists' safety. Fig. 2 illustrates the Plateau neighborhood in the context of the Montreal region. Within the Plateau, this paper focuses on a small sub-area which is experiencing increasing traffic volumes and speeds along several local residential corridors which include several daycares, schools, churches, and community centers. Fig. 3 presents the Plateau road network featuring morning peak-period link speeds (highly congested) and highlighting the sub-area where traffic calming is proposed.

In order to investigate the effects of traffic calming, we identified seven different scenarios including isolated and network-wide measures. The identified measures included speed bumps (raised areas in the roadway pavement surface that are less than 0.3 m in width and are crossed at very low speeds of 5–10 km/h), speed humps (raised areas in the roadway