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Cycleways and footpaths: What separation is needed for equivalent air pollution dose between travel modes?

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ABSTRACT

Cycling and walking are being promoted in many urban areas as alternatives to motorised transport for health, environmental, and financial reasons. The reduced congestion and resulting decrease in the overall amount of pollution reduced can be expected to result in health benefits for the community. However, active commuters, due to their increased respiration rates and often increased travel times can expect to receive larger doses of air pollution compared with those using motorised forms of transport. However, given the large dropoff in concentrations away from a road, it can be expected that significant reductions can be achieved even with relatively small increases in separation between the path of cyclists/pedestrians and motor vehicles.

This study presents a simple methodology for calculating the separation needed for cyclists and pedestrians to experience the same air pollution dose as car commuters. An example is given based on carbon monoxide (CO) data collected in a field campaign consisting of a car driver, a cyclist and a pedestrian travelling on a 2600 metre loop of road in Auckland. For this case study, the estimated distance from the centreline needed for cyclists and pedestrians to receive an equivalent dose of CO as motorists was found to range from 5.8 to 14.2 m depending on the commuting mode and the dispersion state of the atmosphere at the site. This was equal to a CO concentration reduction of 0.1–0.14 ppm per metre. Recommendations on facility modifications and route selections have been made to make active mode commuting safer.

Introduction

Many cities around the world actively promote cycling and walking as strategies for improving the sustainability of transport systems. Examples include the Barclays Cycle Superhighways in London (Transport for London, 2014), the Portland Bike Share initiative in Portland, Oregon (Portland Bureau of Transportation, 2014), and cycling encouragement programmes in many cities in continental Europe (Pucher and Buehler, 2008). Auckland, New Zealand is no exception with the development of cycleways and improved pedestrian footpaths being central to the transport component of Auckland's Unitary Plan as it tackles rapid population growth and aspirations to become the world's most liveable city (Auckland Council, 2014).

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There are many known direct benefits for the cyclists themselves, including improved physical health, fitness, mental health, and general sense of well-being (Pucher and Buehler, 2008; Reynolds et al., 2009). Indeed, a recent study carried out in Auckland found improvements to health and fitness as the primary motivator for existing cyclists to cycle (Wang et al., 2012). For those who do not cycle and would consider cycling, the main obstacle to cycling was reported as being 'inadequate infrastructure' and 'safety concerns' (Wang et al., 2012). Very similar conclusions have also been formulated for urban areas in other cities around the world (Kingham et al., 2001; Daley et al., 2007; Pucher et al., 2010).

To improve safety and encourage transport by bicycle, cities are developing their cycling infrastructure, such as 'cycle superhighways' (Transport for London, 2014). Multi-objective algorithms are currently being developed to ensure that links within networks are expanded in a way that is optimal for the commuters using them and present maximum benefits for future cyclists currently inhibited by the lack of such infrastructure. Factors that are considered in such optimization models include travel time, risk of accidents, cost to build, topography, and air pollution exposure (Kingham et al., 2001). The air pollution exposure algorithms in Wang et al. (2012), specifically designed for Auckland, make use of information emerging from multimodal travel air pollution exposure studies. Such studies, carried out internationally, have generally found differences in air pollution exposure between bus, car, bicycle and pedestrian commuters, with a tendency for lower levels experienced by cyclists and further reductions for pedestrians (Kaur et al., 2007), information that is inadequately achieved on the basis of fixed monitoring alone (Sarnat et al., 2001; Kim et al., 2005; Sarnat et al., 2006; Lim et al., 2012). The main reason given for these lower exposures is the increased separation from the main line of traffic which contains near-undiluted traffic emissions (Hudda et al., 2011).

This is supported by studies such as that of Karner et al. (2010) which showed that concentrations of carbon monoxide drop to less than 50% of roadside levels 150 metres from the edge of major roadways, and others have observed decreasing gradients with distance from roads (Brauer et al., 2003; Zhu et al., 2004; Mukerjee et al., 2009). However, little is known about the spatial variability of pollution in the transport microenvironment, on the road itself, in the order of one to ten meters from the road edge.

CO concentrations have demonstrated rapid downward trends due to improved vehicle emission technology in most of the developed-world's cities (Fenger, 1999). However, the availability of portable CO sensors which are suitable for mobile monitoring applications have made CO an important gas to monitor because it can be used as an indicator, or a tracer gas for vehicular tailpipe emissions. Many personal exposure studies have used CO in such a manner (Kaur et al., 2007).

Other important considerations when comparing air pollution doses between modes of commuting is the time spent in the road corridor (the travel speed) and also the rate of uptake of pollutants (the active modes, by definition, result in higher ventilation rates and hence higher rates of uptake of pollutants). Studies have shown that air pollution dose (taking into account not only the concentrations of pollutants but also the travel time and breathing rates) is higher for cyclists and pedestrians compared to car commuters, despite the lower concentrations experienced by the active mode commuters (Gulliver and Briggs, 2007; Boogaard et al., 2009; Dirks et al., 2009; Int Panis et al., 2010; Dirks et al., 2012). This increase in pollutant dosage must be carefully managed because of active commuting modes being encouraged and promoted in many urban areas due of environmental concerns, cost, and perceived health benefits (Berghmans et al., 2009; Boogaard et al., 2009; Tiwary et al., 2011).

When optimising new cycleways, exposure to air pollution and air pollution dose as determined by the separation of the cycleway or indeed the footpath in the case of pedestrians are important considerations. Studies which improve our understanding of the role of separation distance in determining ambient pollutant exposure and dose are urgently required to minimise exposure and ensure appropriate design of cycle- and walking-friendly transportation networks. There is also a need to adequately quantify air pollution concentration dropoff as a function of separation distance so these data can be integrated into optimisation algorithms.

This paper presents a study of carbon monoxide concentration dropoff from the road edge for a site in Auckland, New Zealand during peak traffic periods, in order to quantify air pollution dose as a function of separation from the road for cyclists and pedestrians. Ultimately, the objective is to determine what separation is needed to ensure that cyclists and pedestrian experience the same air pollution dose, taking into account commute time and increased breathing rate, compared to a car commuter travelling on the same stretch of road. This can be used as a basis in cost-benefit analysis in optimisation routines for the development of cycling and pedestrian infrastructure.

Methods

Study site

The location of the study site was Meola Road in Auckland, New Zealand, the country's largest city with 1.4 million inhabitants (Fig. 1). Meola Road is located in Point Chevalier, a western suburb of Auckland City and has a weekday traffic count average of 12 100 vehicles per day in both directions (Auckland Transport, 2013). Meola Road has a number of attributes which made it suitable for this study: (*i*) the road has been classified as an arterial road and is regionally significant (Auckland Regional Transport Authority, 2009), (*ii*) to the north and south of the transport corridor, there is substantial green space which isolates the transport corridor somewhat from emissions from other activities, (*iii*) and it is sufficiently wide to have pedestrian and cycling facilities (Supplementary material: Fig. A.1). The immediate surroundings include residential