Environment International 74 (2015) 281–290

Contents lists available at ScienceDirect

Environment International

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

# Traffic-related air pollution and health co-benefits of alternative transport in Adelaide, South Australia

Ting Xia [a], Monika Nitschke [b], Ying Zhang [c,*], Pushan Shah [d], Shona Crabb [a], Alana Hansen [a]

[a] School of Population Health, University of Adelaide, Adelaide, Australia
[b] The Department for Health and Ageing, South Australia, Australia
[c] School of Public Health, University of Sydney, Sydney, Australia
[d] Environment Protection Authority, South Australia, Australia

ARTICLE INFO

Article history:
Received 9 May 2014
Accepted 4 October 2014
Available online 9 November 2014

Keywords:
Active transport
Public transport
Air pollution
Health impact assessment
Physical activity
Traffic injury

ABSTRACT

*Background:* Motor vehicle emissions contribute nearly a quarter of the world's energy-related greenhouse gases and cause non-negligible air pollution, primarily in urban areas. Changing people's travel behaviour towards alternative transport is an efficient approach to mitigate harmful environmental impacts caused by a large number of vehicles. Such a strategy also provides an opportunity to gain health co-benefits of improved air quality and enhanced physical activities. This study aimed at quantifying co-benefit effects of alternative transport use in Adelaide, South Australia.

*Method:* We made projections for a business-as-usual scenario for 2030 with alternative transport scenarios. Separate models including air pollution models and comparative risk assessment health models were developed to link alternative transport scenarios with possible environmental and health benefits.

*Results:* In the study region with an estimated population of 1.4 million in 2030, by shifting 40% of vehicle kilometres travelled (VKT) by passenger vehicles to alternative transport, annual average urban $PM_{2.5}$ would decline by approximately 0.4 $\mu g/m^3$ compared to business-as-usual, resulting in net health benefits of an estimated 13 deaths/year prevented and 118 disability-adjusted life years (DALYs) prevented per year due to improved air quality. Further health benefits would be obtained from improved physical fitness through active transport (508 deaths/year prevented, 6569 DALYs/year prevented), and changes in traffic injuries (21 deaths and, 960 DALYs prevented).

*Conclusion:* Although uncertainties remain, our findings suggest that significant environmental and health benefits are possible if alternative transport replaces even a relatively small portion of car trips. The results may provide assistance to various government organisations and relevant service providers and promote collaboration in policy-making, city planning and infrastructure establishment.

## 1. Introduction

Fossil fuel combustion by motor vehicles is a major source of greenhouse gases (GHGs). It is estimated that 23% of the world's energy-related GHG emissions are attributed to transport systems, and nearly three quarters of these emissions are due to land transportation (Kahn Ribeiro et al., 2007). Meanwhile, exhaust fumes from motor vehicles contain air pollutants such as nitrogen dioxide ($NO_2$), volatile organic compounds (VOCs), carbon monoxide (CO) and particulate matter (PM), which disperse ubiquitously. Epidemiological and toxicological studies have recently provided strong evidence that vehicle-related emissions have a relationship with clinically significant health outcomes (Gan et al., 2011; Tsai et al., 2010; Ye et al., 2000). A large portion of PM is contributed to the ambient environment through combustion processes and according to the European Topic Centre on Air and Climate Change (2005) data (European Topic Centre on Air and Climate Change, 2005), road transport accounts for 18.4% of total PM emissions worldwide. The last 20 years have brought more certainty about the range of health outcomes associated with PM (Barnett et al., 2006; Hansen et al., 2012). High concentrations of PM have been found to be associated with the risk of lung cancer (Vineis et al., 2006), respiratory (Medina-Ramon et al., 2006) and cardiovascular diseases (Gan et al., 2011). Therefore, PM is a major environmental risk factor to global public health and has been used by World Health Organization (WHO) as an indicator of air pollution exposure (WHO, 2009a).

Programs to change travel behaviours, including the increased use of public transit and active travel, are essential in reducing transport GHG emissions and the adverse health effects of air pollution. Aside from improving air quality, active transport options also encourage individuals to achieve recommended levels of physical activity. Daily,

---

* Corresponding author at: School of Public Health, Edward Ford Building (A27), The University of Sydney, NSW 2006, Australia. Tel.: +61 2 9114 1417.
E-mail address: ying.zhang@sydney.edu.au (Y. Zhang).

http://dx.doi.org/10.1016/j.envint.2014.10.004
0160-4120/

moderately intense physical activity of approximately 30 min duration can contribute to the reduction of all-cause mortality, and especially to a decreased risk of cardiovascular disease, type II diabetes, breast cancer, colon cancer and dementia (Penedo and Dahn, 2005; Warburton et al., 2006). Similar associations between active transport and population health have also been identified (Oja et al., 2011; Xu et al., 2013).

Recently, a number of studies have attempted to quantify the overall health co-benefits of replacing car travel with alternative transport (Macmillan et al., 2014; Maizlish et al., 2013; Rojas-Rueda et al., 2012). For instance, a UK study (Woodcock et al., 2009) projected the environmental and health benefits of various alternative transport scenarios for 2030 in London. The study indicated that over 500 premature deaths and over 7000 disability-adjusted life-years (DALYs) could be saved under alternative transport scenarios. Similarly, Grabow et al. (2012) found that by eliminating short motor vehicle trips in 11 metropolitan areas in the upper mid-western United States, the annual average urban rate of $PM_{2.5}$ would decline by 0.1 $\mu g/m^3$, resulting in net health benefits of 1295 fewer deaths/year because of improved air quality and enhanced physical activity.

It has been estimated that urban air pollution contributes approximately 1% to the total burden of disease in Australia (Begg et al., 2007), with 900 to 2000 premature deaths annually attributed to traffic-related ambient air pollution (BITRE, 2005). Australia has one of the highest rates of motor vehicle ownership, with over 90% of Australian households having one or more registered motor vehicles (ABS, 2012). Public transport and active travel trips only account for a small portion of total trips in Australia (ABS, 2012) despite the fact that in major cities, approximately 20% of trips to work are less than 5 km (ABS, 2012), a distance that could easily be replaced by active transport such as bicycle riding or even walking.

Recently, several studies have been carried out to assess the cost–benefit of active transport use in Australia, both at the city and country levels (Cobiac et al., 2009; Fishman et al., 2011; Mulley et al., 2013). However, none of these studies factor in benefits from air pollution reduction or use of public transport. In the present study, we aim to not only assess health benefits of replacing the use of passenger vehicles with cycling, but also quantify GHG reduction and potential health impacts associated with a travel model change to public transport and active transport.

## 2. Materials and methods

### 2.1. Study setting

Adelaide, the capital city of South Australia, is the fifth-largest city in Australia. As a medium sized city, the metropolitan area occupies around 870 $km^2$ with a population of 1.1 million in 2010. The public transportation infrastructure includes over 4500 km of bus routes, 120 km of train lines, 15 km of tram lines and a 770 km network of bicycle lanes (Government of South Australia, 2013). However, over 80% of the residents in South Australia travel by private motor vehicle, whilst public transport and active transport only account for 12% and 3% respectively (ABS, 2012). Approximately 18% of private car trips are shorter than 5 km, and 20% are 5–10 km. Thus, short trips in metropolitan areas could be relatively easily replaced by cycling. Although Adelaide has relatively low levels of air pollution, a recent local study suggested an increased cardiorespiratory morbidity associated with increases in ambient levels of $PM_{2.5}$ (Hansen et al., 2012).

### 2.2. Theoretical framework

This case study explored the effect on health outcomes in Adelaide of replacing a proportion of the vehicle kilometres travelled (VKT) by passenger vehicles, with public transport and cycling. First, we designed a number of experimental scenarios based on the baseline VKT. We used $PM_{2.5}$ as the major indicator of air pollution, due to the association with all-cause mortality and because the effects of other vehicular pollutants on mortality become less significant when controlling for $PM_{2.5}$ (Pope et al., 2002). Second, we used the Motor Vehicle Emission Inventory to calculate changes in the GHG and $PM_{2.5}$ emissions generated by motor vehicles and then included the findings into the air pollution dispersion model (TAPM) to estimate the traffic-related $PM_{2.5}$ concentrations for each scenario. Third, a health impact assessment model based on the comparative risk assessment approach (CRA) (Ezzati et al., 2004) was adapted to quantify changes in the burden of disease associated with a reduction of particulate air pollution, and increased physical activity (taking into account future population projections). Changes in traffic injuries were estimated by using a traffic injury matrix approach. Sensitivity analysis was then conducted to estimate the degree of uncertainty in our modelling. Fig. 1 shows the overall theoretical framework used for assessing the co-benefit effects of alternative transport in this study.

### 2.3. Baseline vehicle kilometre travelled and emissions

We selected 2010 as the baseline year. Baseline VKT and vehicular emissions were estimated using the Motor Vehicle Emission Inventory provided by the Environment Protection Authority (EPA) in South Australia. This inventory contains local traffic information including annual average daily traffic counts and percentage distribution of different vehicle types for over 15,000 road links derived from the Adelaide strategic transport model. Emission factors for $PM_{2.5}$ (gram/km) calibrated to Australian vehicles and traffic data were used to calculate exhaust-related $PM_{2.5}$ emissions (grams/per day) for each link.

### 2.4. Scenarios

The scenarios refer to the 30-Year Plan for Greater Adelaide (Government of South Australia, 2010) and use transport behaviour in the Netherlands, a country with high levels of walking and cycling, as a scenario example. Hence, we used five scenarios of reductions in passenger vehicle VKT, ranging from 5% to 40%. These were based on the Motor Vehicle Emission Inventory and the latest Transport Use Survey (ABS, 2012). Table 1 presents data relating to VKT at baseline 2010, business-as-usual (BAU) by 2030 and each of the five scenarios. The BAU estimates represent the potential future trajectories for land transportation in the absence of reduction options. Accordingly, the total VKT by all types of vehicle in the 2030 BAU scenario were projected using the 2010 baseline allowing for an annual growth rate of 2.4% in all types of vehicles as indicated in the Bureau of Infrastructure, Transport and Regional Economics report (2011). The reduction in passenger vehicle use scenarios included various hypotheses regarding the extent of VKT reductions. For each reduction scenario, we assumed that only VKT for passenger vehicles would be replaced by alternative transport, while VKT for other commercial vehicles (e.g. heavy-duty vehicles) would keep increasing at a stable annual growth rate.

The increase in cycling scenarios for 2030 assumed a shift from passenger vehicles to cycling by additional cyclists, resulting in a 5% and 10% reduction in passenger VKT in Scenarios 1 and 2 respectively. The increased public transport use scenarios assumed that 20% and 30% of passenger VKT would shift to public transport. The ‘Towards Alternative Transport’ scenario (TAT) assumed that a total of 40% of the kilometres travelled by passenger vehicles would be replaced by alternative transport options (including public transport and cycling), presenting a significant change in travel patterns.

### 2.5. Air pollution estimates

#### 2.5.1. Traffic-related $PM_{2.5}$ and $CO_2$ emission model

We used the 2010 baseline emission data to project the $PM_{2.5}$ emissions in 2030 BAU and each reduction scenario (Table 2). Firstly, we multiplied emission factors by estimated VKT to calculate the amount