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Impacts on air pollution and health by changing commuting from car to bicycle

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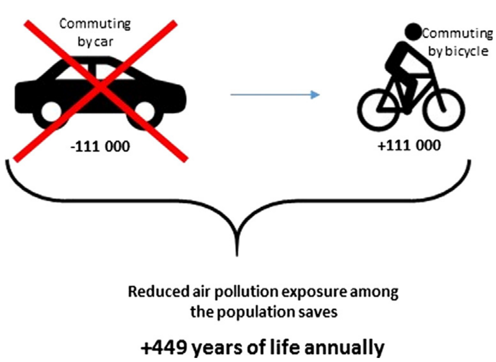
HIGHLIGHTS

- A very large potential for transferring car commuters to cycling; more than 111 000 car commuters shifting.
- Reduced vehicle emission and thereby reduced population exposure, saves 449 years of life annually in Stockholm County.
- This is more than double the effect estimated in connection with the introduction of congestion tax in Stockholm.

GRAPHICAL ABSTRACT



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ABSTRACT

Our study is based on individual data on people's home and work addresses, as well as their age, sex and physical capacity, in order to establish realistic bicycle-travel distances. A transport model is used to single out data on commuting preferences in the County Stockholm. Our analysis shows there is a very large potential for reducing emissions and exposure if all car drivers living within a distance corresponding to a maximum of a 30 min bicycle ride to work would change to commuting by bicycle. It would result in >111,000 new cyclists, corresponding to an increase of 209% compared to the current situation.
Mean population exposure would be reduced by about 7% for both NO_x and black carbon (BC) in the most densely populated area of the inner city of Stockholm. Applying a relative risk for NO_x of 8% decrease in all-cause mortality associated with a 10 $\mu g\ m^{-3}$ decrease in NO_x, this corresponds to >449 (95% CI: 340–558) years of life saved annually for the Stockholm county area with 2.1 million inhabitants. This is more than double the effect of the reduced mortality estimated for the introduction of congestion charge in Stockholm in 2006. Using NO_2 or BC as indicator of health impacts, we obtain 395 (95% CI: 172–617) and 185 (95% CI: 158–209) years of life saved for the population, respectively. The calculated exposure of BC and its corresponding impacts on mortality are likely

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Mortality
Cycling

underestimated. With this in mind the estimates using NO_x, NO_2 and BC show quite similar health impacts considering the 95% confidence intervals.

1. Introduction

Road vehicle emissions are one of the most important sources of human exposure to air pollution. Depending on pollutant, mode of travel, travel distance etcetera, the exposure while commuting during rush hours along densely trafficked corridors may constitute a substantial fraction of the total daily exposure (e.g. Hänninen et al., 2004; Barrett et al., 2008; Dons et al., 2012). High exposures occur both inside vehicles due to the proximity of air intakes to exhaust emissions from neighboring vehicles as well as while walking or biking alongside the roads (Dons et al., 2012).

In the last years there have been attempts to develop estimates of the overall impact of transferring journeys from car to bicycle (de Hartog et al., 2010; Lindsay et al., 2011; Rojas-Rueda et al., 2011; Grabow et al., 2012). A Dutch study quantified the potential impact on all-cause mortality in 500,000 people that would make a transition from car to bicycle for a 7.5 or 15 km commute (de Hartog et al., 2010). In a similar study in Barcelona the change in cyclist exposure to exhaust was estimated (Rojas-Rueda et al., 2011). A study from New Zealand (Lindsay et al., 2011) shifting 5% of the vehicle kilometers to cycling, and an American study shifting 50% of car trips <8 km to cycling (Grabow et al., 2012), both included estimates also of how the general population's health would benefit from reduced exhaust emissions.

These studies discuss specific cities, but all use very hypothetical scenarios and journeys. In an even more general European perspective, the benefits were estimated per individual driver who switches to active transport (5 km for bicycling and 2.5 km for walking) (Rabl and de Nazelle, 2012). Even if the published health impact assessments generally estimate very large potential benefits for commuters, the population wide benefits and interactions are not so well described (de Nazelle et al., 2011; Teschke et al., 2012).

Based on the results of a national travel survey in Sweden with thirty-nine thousand interviews conducted on a daily basis during 2011–2014 (Trafikanalys, 2015), we calculate that 51% of all car trips were shorter than 7.5 km. This means that the potential to shift car drivers to bicycles should be large. However, common objections relate to the Nordic climate, increased dose of traffic pollutants and injuries among cyclists, and especially, limited interest in the segments of the population who does not use a bicycle.

The main objective of this work is to assess the effect on emissions and population exposure of transferring car commuters to cyclists. Earlier studies on this matter have been based on hypothetical scenarios. Our scenario is based on detailed information on the individuals' home and work addresses, empirical data to establish which distances are reasonable to travel by bicycle and a transport model to single out data on commuting preferences in the County of Stockholm. This provides us with a possibility to demonstrate an integrated environment and health impact assessment built on realistic assumptions. This is useful for policy making and interventions.

2. Methods

Fig. 1 illustrates the different steps in the calculation of the population and commuter exposure and each step is described in the following sections. The basic data used for identifying individuals who can shift from car to bicycle are: 1) individual data on home and work addresses, age, sex and car ownership, 2) travel times and travel costs, and 3) traffic network data and vehicle fleet emission factors. The calculation steps are:

i) identify current volume of car commuting and the distance from home to workplace if these trips were made by bicycle based on the Astrid database and a travel demand model (LuTrans), both described later,
ii) calculate travel times by bicycle for current car commuters depending on sex and age considering their physical capacity based on physical capacity modelling,
iii) identify commuters with a travel time by bicycle of less than or equal to 30 min,
iv) calculate the new traffic flows, where remaining traffic may choose a different route based on the LuTrans travel demand model,
v) calculate spatially resolved reduction in air pollutant emissions and concentrations due to shifting car to bicycle commuting based on emission factors and the change in traffic due to less car commuters (here we take into account that the number of car commuters is slightly higher than the number of drivers (i.e. cars), why it is possible that more car commuters would shift to cycling than we now assume),
vi) calculate change in population weighted average exposure of the general population based on home address and spatially resolved concentrations,
vii) calculate the number of premature deaths avoided based on change in population exposure and exposure response functions for different pollutants, and
viii) calculate years of life gained for the population based on life table statistics for the population.

Below we describe the models and data bases used in each step.

2.1. Scenario building through modelling of traffic flow and expected individual bicycle speed

2.1.1. Current modes of travel

Travel survey data was used to obtain an estimate of the proportion currently traveling to work with each mode of transport; walking, bicycling, public transport and car. These proportions were estimated on a fairly high resolution of combinations of living and work areas, where the size of each statistical area depend on the population density but also considering natural division of neighborhoods. Individual information on age, gender, home and work address and car ownership was obtained from the ASTRID database (Stjernström, 2011). This data was linked with the LuTrans model (Jonsson et al., 2011) together with data on traffic flows on roads. The LuTrans model is regularly calibrated based on traffic counts and the travel output is modelled as a logit model of: 1) travel survey data allocating individual trips to different modes of transport and 2) traffic counts to allocate car tips to specific car routes. The output is traffic flow on each link in the model, where a link is defined as the connection between two major intersections in the road network. In the present form there are auto links and public transport links included in the model. We allocated all study subjects a current mode of transport between home and work place.

2.1.2. Duration-distance relations considering physical capacity

As mentioned above, the methodology to obtain realistic duration-distance relations involves several steps, which are described in detail by Schantz et al. (2017). The first step was to establish the duration-distance relations in about 450 cycle commuters. For that purpose, the participants drew their own normal cycle commuting route to work on a