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The effects of congestions tax on air quality and health

Christer Johansson [a,b,*], Lars Burman [b], Bertil Forsberg [c]

[a] *Department of Applied Environmental Science, Stockholm University, S-106 91 Stockholm, Sweden*
[b] *Stockholm Environment and Health Administration, Box 8136, S-10420 Stockholm, Sweden*
[c] *Occupational and Environmental Health, Umeå University, S-901 87 Umeå, Sweden*

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ABSTRACT

The "Stockholm Trial" involved a road pricing system to improve the air quality and reduce traffic congestion. The test period of the trial was January 3–July 31, 2006. Vehicles travelling into and out of the charge cordon were charged for every passage during weekdays. The amount due varied during the day and was highest during rush hours (20 SEK = 2.2 EUR, maximum 60 SEK per day). Based on measured and modelled changes in road traffic it was estimated that this system resulted in a 15% reduction in total road use within the charged cordon. Total traffic emissions in this area of NO_x and PM10 fell by 8.5% and 13%, respectively. Air quality dispersion modelling was applied to assess the effect of the emission reductions on ambient concentrations and population exposure. For the situations with and without the trial, meteorological conditions and other emissions than from road traffic were kept the same. The calculations show that, with a permanent congestion tax system like the Stockholm Trial, the annual average NO_x concentrations would be lower by up to 12% along the most densely trafficked streets. PM10 concentrations would be up to 7% lower. The limit values for both PM10 and NO_2 would still be exceeded along the most densely trafficked streets. The total population exposure of NO_x in Greater Stockholm (35 × 35 km with 1.44 million people) is estimated to decrease with a rather modest 0.23 $\mu g\ m^{-3}$. However, based on a long-term epidemiological study, that found an increased mortality risk of 8% per 10 $\mu g\ m^{-3}$ NO_x, it is estimated that 27 premature deaths would be avoided every year. According to life-table analysis this would correspond to 206 years of life gained over 10 years per 100 000 people following the trial if the effects on exposures would persist. The effect on mortality is attributed to road traffic emissions (likely vehicle exhaust particles); NO_x is merely regarded as an indicator of traffic exposure. This is only the tip of the ice-berg since reductions are expected in both respiratory and cardiovascular morbidity. This study demonstrates the importance of not only assessing the effects on air quality limit values, but also to make quantitative estimates of health impacts, in order to justify actions to reduce air pollution.

1. Introduction

Many cities have implemented congestion charging or low emission zones aiming at reducing traffic congestion and health impacts of traffic emissions. In Singapore traffic congestion was alleviated using first a manual Area licensing scheme starting in 1975 and subsequently an Electronic Road pricing system (ERS) from 1998 (Seik, 2000). London has a road charging zone around the city centre that recently was updated to cover a larger area. Several Norwegian cities charge drivers travelling with studded winter tires in order to reduce particle emissions due to road wear. In Rome, traffic is prohibited in the inner city on weekdays. Several cities in Europe have low emission zones. In several Swedish cities low emission zones

* Corresponding author. Department of Applied Environmental Science, Stockholm University, S-106 91 Stockholm, Sweden. Tel.: +46 709 38 30 86.
E-mail address: christer.johansson@itm.su.se (C. Johansson).

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apply to trucks and buses. Recently three German cities (Berlin, Hannover and Cologne) have applied a complete ban on all vehicles that have no catalysts or diesel particulate filters in zones of the city centres.

However, so far, there are very few papers on the quantitative effects of road pricing or low emission zones on air pollutant concentrations, population exposure and health. Beevers and Carslaw (2005) analyzed the air pollution impact of the London congestion charging. Road traffic data, combined with a traffic emission model, indicate that NO_x and PM10 emissions have been reduced by about 12% in the charging zone. But the emissions have increased on the inner ring road. The overall impact on air quality and health was not assessed. To our knowledge there is only one earlier study (Tonne et al., 2008) that has assessed the effects of a charging scheme not only on traffic and emissions, but also on exposure concentrations and health. They used a combination of dispersion modelling and regression calculations to analyse the air pollution and mortality benefits of the London congestion charge scheme (CCS). They concluded that the CCS lead to reductions in concentrations, although modest across Greater London, but greater in the charging zone wards. Predicted health benefits in the charging zone wards were 183 years of life per 100 000 people assuming conditions would persist over 10 years. This paper describes the effects of a road charge system in Stockholm on emissions, levels of air pollutants, and health of the population.

2. Description of the road charging system

On June 2, 2003, Stockholm City Council proposed testing congestion charging of traffic – called "The Stockholm Trial". On June 16, 2004 the Swedish Parliament adopted a law that made it possible to charge a congestion tax in Stockholm up to July 31, 2006. The Stockholm Trial consisted of three parts: extended public transport (16 new bus lines), congestion tax and more park-and-ride sites in the city and the county. The total public transport service was extended by 7% and the park-and-ride capacity was extended by 29%. The objectives of the trial included (i) reducing the number of vehicles in the congestion-charging zone during the morning and afternoon by 10–15%, (ii) improving traffic flows on the most heavily trafficked roads and (iii) reducing emissions of carbon dioxide, nitrogen oxides and particles in inner city.

Fig. 1 shows the extent of the congestion zone and the location of the toll stations. The inner city area is approximately 6 km $\times$ 6 km and has around 350 000 inhabitants. There are 23 000 workplaces, employing 318 000 persons of which two-thirds come from outside the zone. Drivers paid every time they passed a toll station (Table 1). Highest amount due was 20 SEK (corresponding to 2.2 EUR) during rush hours and lowest amount (10 SEK) early in the morning or in the evening. Maximum amount to pay for one day was 60 SEK. Night-time, holidays and weekends were free of charge. Taxis, buses, motorcycles, and cars classified as environmental vehicles (e.g. driven by electricity or bio fuels) were exempted. The Essingeleden bypass (Fig. 1) was free of charge for passage north–south through the toll zone.

3. Methodology

3.1. Measurements and modelling of road traffic

The effect of the Stockholm Trial on road traffic was quantified in terms of traffic flow by counting vehicles and by calculating road use, i.e. the number of vehicle kilometres travelled in the area (e.g. Baradaran et al., 2006; Forsman et al., 2006). Congestion was quantified in terms of journey times obtained from floating car measurements or from traffic cameras. Data on the composition of the vehicle fleet were acquired from manual recording of vehicle types over stretches of road where the control points already existed before the trial. For details evaluation reports in English are available on http://www.stockholmsforsoket.se/templates/page.aspx?id=12555 (accessed August 2008).

3.2. Calculation of emissions

3.2.1. Emission factors

The estimate of the change in road use with the Stockholm Trial was implemented in an existing traffic database (Airviro, SMHI, Norrköping, Sweden; http://airviro.smhi.se) (Johansson et al., 1999). Emissions from road traffic are described with emission factors for passenger cars (petrol and diesel), light commercial vehicles, heavy goods vehicles. Emission factors for NO_x were obtained from the EVA model of the Swedish Road Administration (Hammarström and Karlsson, 1994). Emission factors for PM10 were obtained from simultaneous measurements of PM10 and NO_x in the street canyon of Hornsgatan and at the urban background site (Torkel Knutssonsgatan), using NO_x as quantitative tracer as described in Ketzel et al. (2007). Emission factors for other roads were corrected for the vehicle speed dependence according to Bringfelt et al. (1997).

3.2.2. Uncertainties in emissions

There are several uncertainties in the estimation of the change in emissions due to congestion charging. Emission factors for NO_x depend on fleet composition and driving conditions (speed and congestion). With congestion charging, the relative contribution from commercial vehicles, especially heavy-duty vehicles, increased. This effect was not considered for every individual street. Instead the mean change in fleet composition was applied to all roads within the inner city.

Queuing time was reduced during the Stockholm Trial by one-third during the morning and by more than half during the afternoon/evening compared to without the trial (Söderholm, 2006). Estimates by Carlsson et al. (2006) using the Artemis emission factors indicate that reduced traffic congestion lead to a small reduction in the emissions of NO_x and exhaust PM, on the order of 1% for the whole day and 2–3% for rush hours. As shown below the reduction in emissions due to less traffic is much larger. Higher vehicle speeds increase vehicle-induced turbulence and may then increase dilution, especially during periods with low wind speed (Kastner-Klein et al., 2000), further decreasing the concentrations. The overall net effect on the emissions and concentrations for all streets of the area is