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The air quality impact of cordon and distance based road user charging: An empirical study of Leeds, UK

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Abstract

Traffic assignment, pollutant emission and dispersion models were applied to a major UK city so as to assess the air quality impacts of five road pricing schemes. Schemes were evaluated with reference to: exceedence of air quality standards for six pollutants; greenhouse gas emission; redistribution of pollution, an environmental justice concern; and road network performance as traffic speed and trip distance. Results were compared to alternatives of do nothing, network development and clean fuel promotion. The air quality benefits of a modest distance-based charge are highlighted. However, whilst road pricing shows potential as an air quality management tool, its value and suitability are strongly sensitive to prior air quality and emission source apportionment in the application city.

Keywords: Air quality management; Urban; Road pricing; Traffic emission; Dispersion modelling

1. Introduction

Exceedence of air quality standards is common for European cities (EEA, 1998). This is a significant threat to public health, with an estimated 24 000 premature deaths per annum attributed to poor air quality in the UK alone (DoH, 1998). The EC air quality framework directive (96/62/EC) requires member states to eliminate standard exceedences for a range of pollutants by defined target dates. To achieve these objectives, the UK has developed a national air quality strategy (NAQS) that defines policy, tasks and responsibilities for air quality management (DETR, 2000a). Under the NAQS local government is responsible for assessing future air quality and for establishing air quality management areas and action plans where objectives are not expected to be achieved.

Road transport, now the main source of atmospheric emissions in Western Europe (EEA, 1998), is a key focus of the NAQS. In addition to reducing congestion, tackling pollution is also a major objective of European transport pricing policy (CEC, 1995) and the UK government's national transport strategy (DETR, 1998a). This strategy includes a five yearly local transport planning process, the 2000 ten year transport plan, and a range of new powers for local authorities, including, controversially, the power to levy charges for road use (DETR, 1998b). London was amongst the first authorities in the UK to exercise these powers, introducing a £5 cordon charge to enter central London from February 2003. Initial appraisal shows reductions in traffic, congestion and emissions but to date, reliable evidence on changes in air quality (pollutant concentrations) has not been forthcoming due to atypical meteorology (TfL, 2005).

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Other cities have not followed London's lead, as authorities are sensitive to the possible adverse public reaction (indeed citizens of Edinburgh rejected road pricing in a 2005 referendum), hence the London experience is being watched closely to better assess possible benefits. Evidence for congestion reduction comes mostly from desk studies. These indicate that greater benefits accrue from road pricing implemented as part of an integral approach, with charging reinforcing other strategic measures such as improved public transport provision (May, 1992; May et al., 2000). These studies also suggest that charges levied continuously throughout the road network lead to greater travel benefits than those applied to cross cordons and screenlines (May and Milne, 2000; Fridstrom et al., 2000).

Whilst there is growing evidence for traffic and congestion reduction, the air quality impact of road pricing has not been adequately quantified. For example, the UK government's advisory body on transport recommended distance-based charging for the UK road network, but did not assess the environmental benefits of forecast reductions in traffic and congestion. They assumed such benefits to be positive, and called for research to quantify them (CfIT, 2002). This knowledge gap is significant as local authorities seek to reduce congestion and achieve binding NAQS objectives. Indeed, in addition to price, revenue use and effectiveness, environmental enhancement is a key factor in the public acceptability of road pricing (Jaensirisak et al., 2002).

Environmental impacts are considered in road pricing studies, but not air quality explicitly. Instead emissions act as a proxy when assessing environmental impact (e.g. Ubbels et al., 2002; Beamon and Griffin, 1999) or deriving optimal charges (e.g. Johansson, 1996; Mayeres, 2000). Air quality observations were made in Singapore following the introduction of a road user charge in 1975 (Chin, 1996), but general conclusions cannot be drawn as: an air quality evaluation of the scheme was not attempted; monitoring did not occur over a long enough period to assess the effect of the scheme within the charge zone; and the influence of other factors including better vehicle emission technology, changes in point source emission, and pollutant import from Malaysia, have not been adequately controlled for in the limited long term data that is available. Furthermore, road pricing in Singapore relates to a single scheme design and hence excludes evaluation of alternative schemes, including distance-based charging.

2. Objectives of the Leeds transport—air quality study

To investigate the role of road pricing on urban air quality, a modelling study of Leeds, a medium size (740 000 residents) English city was conducted. Leeds has experienced strong economic growth since 1981, second only to London, and forecasts indicate this growth will continue. Car ownership has risen by 11% in the last decade, and net in-commuting is predicted to grow 50% in the next decade (LDA, 2000), threatening attainment of air quality objectives, and making Leeds a particularly suitable city to study the air quality implications of alternative road transport management options.

The study assessed the impact on air quality of five urban transport planning options: (a) do nothing; (b) cordon-based road user charging; (c) distance-based road user charging; (d) road network development; and (e) greater use of clean fuelled vehicles (CFV). Combined tests were also conducted (Table 1). Each option was assessed with respect to: (i) air quality, as pollutant concentration and exceedence of air quality standards for NO_2, particulates (PM_{10}), CO, SO_2, benzene and 1–3, butadiene; (ii) greenhouse gas (CO_2, NO_X) emission; (iii) spatial redistribution of NO_2 and PM_{10}; and (iv) road network performance, as mean road speed and trip length.

3. Modelling

The study applied TEMMS, software that integrates models of traffic assignment, pollutant emission and dispersion within NAQS modelling standards (DETR, 2000b). TEMMS, and its validation for Leeds, is discussed by Namdeo et al. (2002), whilst its application in the road pricing study is described below.

3.1. Traffic modelling

Within TEMMS, the SATURN traffic assignment suite (Van Vliet, 1982) was used to estimate traffic flows and travel conditions (e.g. travel times, delays, average speeds) for the Leeds road network. SATURN includes: an assignment model, in which drivers choose routes through a network according to Wardrop User Equilibrium principles, based on generalised costs implied by link and turn-specific cost-flow relationships; and a simulation model, in which cost-flow relationships for the assignment are modified, based on a sophisticated representation of the interaction of traffic flows at junctions. These models were applied iteratively until critical outputs satisfied a series of stability criteria. Principle inputs to SATURN are travel demand (a trip origin–destination matrix); and network supply, including network topology, link cost-flow relationships, junction layout and traffic signal settings.

SATURN can be used to test traffic management options by modifying the road network or trip matrix. Road pricing was addressed in the assignment model by additions to generalised travel costs, calculated using