Effectiveness of traffic management measures in improving air quality in European cities

D.M. Elsom

Air Quality Management Research Group, Department of Geography, Oxford Brookes University, Oxford, OX3 OBP, UK
E-Mail: dmelsom@brookes.ac.uk

Abstract

Motor vehicle emissions are the principal cause of a growing number of cities in Europe experiencing poor air quality. This paper examines the air quality effectiveness of selected traffic management measures implemented in European cities. Traffic management measures attempt to reduce total vehicle emissions by creating situations where vehicle engines operate efficiently, by eliminating congestion and smoothing traffic flows. They attempt to reduce the use of private vehicles by encouraging a modal switch from cars to public transport, cycling and walking and by applying measures to minimise the distances between home, work, shops and leisure facilities. Factors influencing the choice and the effectiveness of traffic management measures are discussed such as economic considerations, attitudes of the public, national constraints, and alternative goals for such measures (e.g. lessening congestion in order to improve mobility; reducing motor vehicle accidents). This paper highlight that there are a limited number of assessments available concerning the air quality effectiveness of specific measures in a variety of urban settings. One problem experienced in studies attempting to assess the air quality impacts of traffic management schemes is that rarely is one measure implemented on its own, rather a combination of complementary measures is introduced.

1 Introduction

Growth in the number and use of motor vehicles, especially cars, is the principal cause of many European cities experiencing poor air quality in their city centres and inner areas as well as along arterial routes. In contrast, domestic heating emissions (except where coal is still burned) has generally declined in importance while emissions from industrial plants (e.g. manufacturing, power, refining) and commercial premises (e.g. vehicle spray painting, petrol stations) may be responsible for only very localised pollution problems. Clearly, in the majority of cities today, air quality management needs to give most attention to reducing traffic emissions. This paper examines the selected traffic management measures being implemented to improve air quality in cities in Europe and outlines examples of studies assessing their effectiveness.
2 Traffic management goals

Traffic management measures are intended to reduce total vehicle emissions by creating situations where vehicle engines operate efficiently (e.g. fuel consumption is reduced by eliminating congestion and smoothing traffic flows) and/or by reducing transport demand such that the use of private vehicles is reduced (e.g. measures to encourage a modal switch from private cars to public transport, walking and cycling; land-use planning measures which minimise distances between home, work, shops and leisure facilities and so reduce dependency on cars). Traffic management measures can be adopted long-term and/or short-term (during smogs).

3 Selecting appropriate measures

Most cities have some form of traffic management measures in place already but they are likely to need further measures in order to cope with future growth in traffic. There are many considerations which influence a city’s choice of traffic management measure(s):

(a) economic considerations. Some measures require expensive engineering to be undertaken and are beyond the resources available to some authorities. For example, a metro may be the preferred way of improving a city’s public transport system in order to attract people out of their cars and onto public transport but a guided bus system or improved bus services may be the only option available on economic grounds.

(b) alternative goals. Traffic management measures have long been implemented for their effectiveness in achieving goals other than improving air quality such as reducing traffic flows and congestion in order to improve mobility, cutting down on the number of motor vehicle accidents, and reducing noise levels.

(c) attitudes of the public. Public support for individual measures varies greatly. For example, the introduction of an exclusive residents’ parking zone, for which residents pay a permit, may be welcomed by residents of one district within a city but rejected by another. Weak public support for an implemented measure can lessen its air quality impact considerably as for example when a central area traffic restricted zone simply results in commuters seeking to park in inner city areas as close to the restricted zone as possible rather than switching to public transport for their journey. The cooperation of the public as well as businesses can be improved through publicity and educational campaigns which stress the health (and economic) benefits of the measures.

(d) national constraints. Traffic management measures are initiated at the local or municipal level but may require approval by the regional or national tier of Government. Guidelines may be set down as to what measures are likely to be approved and those which will not. In some cases legislation may prevent adoption of specific measures. For example, the UK Transport Act 1985 deregulated bus services, except in London and Northern Ireland, preventing local authorities from subsidising services.
Air Pollution Modelling, Monitoring and Management 61

(e) uncertainty concerning the air quality effectiveness of measures. Limited research has been undertaken to assess the air quality effectiveness of each measure or combination of traffic management measures. Assessments are needed in a range of urban sizes, densities and forms, topography, climate, etc. The limited number of detailed air quality assessments to date means that the success of many measures, especially those which attempt to reduce vehicle emissions and improve air quality by transferring urban trips from the private car to public transport have sometimes to be judged simply on whether they have achieved the desired modal distribution.

The air quality changes that have been produced by implementing single traffic management measures or a combination of measures for various European cities, especially the smaller cities, are outlined in the following sections. Some measures may displace rather than reduce traffic emissions, shifting the area of poor air quality from one part of the city to another, such that additional measures need to be introduced at the same time to prevent this. Similarly a traffic restraint measure which deters or prevents commuters from using cars needs to be complemented by measures to improve public transport, walking or cycling facilities. It would seem that rarely is a single traffic management measure introduced on its own, rather a package of measures is needed.

4 Traffic restricted zones

Area-wide bans or restrictions on traffic may be very localised (e.g. pedestrianised street) or cover a much wider area (e.g. historical or commercial district). Most city centres in Europe contain some streets that are pedestrianised, sometimes allowing buses and taxis to travel along these streets. Many Italian cities (e.g. Bologna), Swiss cities (e.g. Bern, St Gallen, Geneva) and cities in the Netherlands (e.g. Enschede) have introduced an auto-restricted zone (ARZ) with access permitted only for pedestrians, bicycles, taxis, public transport vehicles and residents. Additional measures are usually needed to ensure that congestion and increased traffic emissions do not occur immediately outside the traffic restricted zone.

In October 1989, after lengthy public consultation, Lubeck, Germany, banned cars from the city centre (about 1 km²) on every first Saturday per month and then from July 1990 on all Saturdays (1000-1800) its old town. Public transport, taxis, the handicapped and later delivery vehicles, residents and hotel guests were given free access. Public transport was improved and the number of parking areas close to the historical area was increased. Emissions of CO decreased by 75 per cent and NOx fell by between 18 and 50 per cent. After nine months the experiment had proved a success and was extended to Sunday; and in May 1995, the decision was taken to expand it in 1996 to all days of the week [1]. In October 1991 a six-month experimental closure to cars on Saturdays was introduced in Aachen, Germany. Saturday Park and Ride facilities have been offered for many years and so Saturday car restraint (with smaller traffic volumes) seemed a logical step especially as the pedestrianised
area of the city was expanding. Park and Ride services operate from seven peripheral sites (the sites being factory and office car parks not used by employees at weekends) and provide a total of 15,000 car spaces. Access to parking was allowed on designated roads with barriers patrolled by guards erected around the areas of limited access. On-street parking was allowed only to residents who were exempted from the restrictions. Motor vehicle traffic decreased by 8 per cent from 44 per cent to 36 per cent while public transport usage rose by 5 to 15 per cent. NO\textsubscript{2} decreased 50 per cent and CO fell to about 40 per cent of the former concentrations. However, in 1996 it was decided that the Saturday limited access area would be abandoned (the Saturday barriers were considered to create a hostile appearance) but the pedestrian areas would be expanded and consolidated (e.g. by closing a route to private cars which had divided the central shopping area) which, in effect, bans cars from the city centre all days of the week [1,2,3,4].

Following a terrorist bombing in London in 1993, the UK Government decided to restrict entry into the City’s financial district by blocking off some entry and exit roads and installing police checkpoints at others. Using traffic flow and speed data, models showed that traffic emissions of CO, HC, NO\textsubscript{x}, CO\textsubscript{2} and PM\textsubscript{0.1} fell by 15-16 per cent within the security cordon, but that emissions increased by 2 per cent immediately outside the cordon due to re-routing of traffic. Monitoring showed that annual average urban background pollution concentrations fell by 12 per cent, a smaller reduction than the emissions as pollution infiltrates into the area from nearby traffic and other sources [5]. Plans are being made to extend this zone for environmental rather than security reasons.

Financial measures such as tolls and area licenses, in which charges are levied on vehicles entering a defined area, can also reduce traffic emissions by deterring some vehicles from entering the controlled area but they may worsen congestion outside the cordon so increasing emissions there. Generally, it is estimated that reductions in vehicle emissions of 10 to 40% can be achieved in the cordoned area but the overall citywide reduction may total only 5% [2,6].

5 Parking restrictions

A wide range of parking restrictions can be applied to deter the proportion of journeys made by private vehicles to the city centre. These include increasing parking charges in the city centre, reducing the number of roadside and public parking spaces (and greater enforcement of illegal parking), restricting the building of new car parks, restricting the parking space allowed for new or even existing businesses, and expanding the parking capacity at Park and Ride sites. However, the effectiveness of parking management is often limited by a high proportion of parking spaces being private and non-residential.

Using five UK cities ranging in size from 180,000 to just over 500,000, Dasgupta et al.[7] estimated that doubling parking charges would reduce car share in the central area by about 13 per cent (from 56 per cent to 43 per cent).
The citywide effect in car share would be a reduction of about 3 per cent and the estimated CO₂ equivalent emissions would be reduced by 1.6 per cent to 3.7 per cent citywide. Halving the number of parking spaces has an even greater effect than doubling parking charges on car use in the central area, cutting the modal share by 36 per cent (from 56 per cent to 20 per cent), though increasing the car share by 5 to 7 per cent in the outer area. Overall, a citywide reduction of between 5 and 8 per cent is achieved, with most former car users transferring to buses. With less traffic in the central area, average vehicle speeds increase by up to 35 per cent. The net effect on CO₂ equivalent emissions is a reduction of 3.5 to 5.5 per cent.

Fribourg, Switzerland, is using zonal assignment and planning techniques to try to reduce high NO₂ levels caused almost exclusively by the daily influx of 23,000 vehicles into the city. Current mobility profiles (parking needs) of employers have been determined in three city zones, defined according to the quality of public transport available. Parking spaces for employers in each zone were then reduced (e.g. by about 30 per cent in the city centre zone). It was estimated that this strategy would reduce traffic volumes by 28 per cent (17 per cent citywide) and projected traffic volumes by 46 per cent in the city centre and that this would reduce NO₂ levels significantly [8]. The Netherlands also relates mobility profiles of businesses and amenities (in terms of employee and visitor intensities, the dependence of employees on car use during their work and the importance of freight transport) to accessibility profiles of locations by different forms of transport. This ABC location policy determines the type of developments which will be permitted in particular locations and parking standards. Locations classified as A are the most accessible by public transport (e.g. close to major railway stations) so businesses are allocated a smaller parking capacity per number of employees than type C locations where the quality of public transport is relatively low. Although the policy applies only to new developments, many municipalities have adopted parking policies consistent with the ABC policy, particularly in city centres and other congested areas.

A negative aspect of restricting parking spaces or raising charges in the city centre is an increase of traffic in nearby streets as motorists seek parking spaces or less expensive ones. Generally, the use of parking measures on their own are estimated to save only 2 to 6% in citywide emissions [9]. To be more effective in reducing emissions, parking measures need to be combined with other measures which encourage a switch from private cars to public transport, cycling and walking.

6 Traffic calming and area-wide speed limits

Residential areas are less likely to exceed air quality standards than city centres but improvements in air quality may be sought especially if such areas are used by commuters as short cuts. Further, traffic restraint measures taken in the city centre may lead to increased traffic seeking parking spaces in adjacent residential areas leading to worsening air quality in these areas unless deterrent
measures are undertaken. Traffic calming measures in residential areas include mini-roundabouts, raised platform junctions, road narrowings and road humps. They attempt to reduce traffic speeds to a lowered speed limit of 30 kph.

Some studies suggest that where drivers respond aggressively to road humps (braking hard on approaching and accelerating away rapidly afterwards until the next hump is encountered) increases in CO and HC emissions may result [9,10]. However, this disadvantage does not apply to horizontal calming measures (mini-roundabouts, chicanes, curves, etc). A diffusion tube survey undertaken before and after the implementation of traffic calming in Exeter, UK, showed that NO\textsubscript{2} levels fell by about one third [11]. Abbott et al.[6] report on a theoretical study of the effects of a slower speed due to traffic calming and indicate that fuel consumption would increase by 25 per cent. Emissions of CO, HC and CO\textsubscript{2} would rise by 25 to 50 per cent while NO\textsubscript{x} emissions would fall by 30 per cent. Assessments of traffic calming measures in a range of German cities suggest that whereas NO\textsubscript{x} emissions were reduced in the range from 38 to 60 per cent, changes in HC emissions ranged from -23 per cent to +10 per cent and changes in CO ranged from +7 per cent to +71 per cent [6]. Generally, studies have highlighted that traffic calming schemes designed to encourage steady driving speeds are more effective in reducing emissions than slow vehicle speeds per se.

Ten year ago, Graz, Austria, introduced traffic calming measures in two small residential areas with such success that in 1991 more than 80 other 30 kph zones were requested by citizen’s groups. The cost and the time needed to create such zones prompted the city council not to use traditional traffic calming zones but to introduce a general 30 kph speed limit for the whole city street network except for priority streets where a 50 kph limit applied. The experiment ran from September 1992 until August 1994 after which it was decided to continue with the general 30 kph speed limit. A survey of households found that there was no change in the mode of transport used and that there was little change (less than 2 per cent) in the routes taken such that, contrary to public expectation, there was no increase in congestion on the priority routes. 170 test drives took place along roads in the city. At one second intervals, the speed, distance and time of the journey were measured in order to estimate emissions from each vehicle at speeds of 50 kph and 30 kph. The largest proportion of emissions in the city comes from priority roads and since there was no significant differences in the mode of transport or choice of route after the introduction of the 30 kph limit, there is no noticeable difference in the level of emissions along these routes. In the 30 kph limit streets, where only 5 to 8 per cent of all vehicle emissions are emitted, there were positive and negative findings with a 3.8 per cent increase in CO emissions and 0.5 per cent increase in HC. The major change concerned NO\textsubscript{x} emissions which were reduced by 24 per cent. For the city as a whole, NO\textsubscript{2} was reduced by 1.9 per cent. Road safety increased and noise levels were reduced in the 30 kph zones [12].
Urban Traffic Control Control systems

Urban Traffic Control (UTC) systems aim to minimise delays and smooth traffic flows so reducing fuel consumption and hence reducing vehicle emissions. If UTC systems are linked with roadside pollution monitors, as planned in the next generation of Urban Traffic Control and Management (UTMC) systems, there exists the potential to reduce emissions at pollution hotspots in the short-term by changing traffic signals to minimise idling and stop-start conditions there.

In Caen, France, in 1986, measurements indicated that the introduction of green waves (signal linkage allowing uninterrupted driving) reduced fuel consumption by more than 20 per cent in the central area. Typically, green waves resulted in CO emissions being reduced by 30 per cent, HC emissions by 25 per cent and NOx emissions by 6 per cent [13].

Measurements in a suburb of Barcelona indicate that fixed traffic control plan systems (which apply a series of alternative control plans at different times of the day) reduced fuel consumption and emissions by 11 to 12 per cent compared with the fixed traffic control stage system (signals operating all day with one regulation schedule using the same time intervals). Further, the more sophisticated dynamic system, which applies the optimum control plan according to the traffic data it receives, achieved reductions of 16 to 17 per cent in fuel consumption and emissions compared with the fixed stage system [14]. Other studies have concluded that the early UTC systems (e.g. TRANSYT) produced fuel savings of up to 15 per cent compared with the fixed stage control systems while upgrading to more modern systems (e.g. SCOOT) can save a further 3 to 6 per cent during peak traffic flows [9,15,16]. This refers to the area controlled by UTC so represents an emission reduction of about 1 to 2 per cent over the whole urban area [15]. Although such systems lead to a reduction in emissions overall there is some concern that reduced congestion may generate more trips from commuters previously deterred from using their cars.

Modern control systems can enable public transport vehicles to have priority at intersections by delaying a red signal until the vehicle has passed through or by having the green light brought forward. The time borrowed from one cycle can be repaid during the next one. The result is to increase the average speed of vehicles along the route and, in the case of buses, this can reduce emissions by 15 to 30%. In most cities in Germany and Switzerland, buses and trams are equipped with signal pre-exemption equipment. Simply giving buses priority at turns alone can save 5% in bus journey times and reduce bus emissions by 7% [10,15]. However, the reduced emissions achieved by giving priority to public transport vehicles may be offset by increased emissions from the rest of the traffic which may be delayed. Nevertheless, giving public vehicles priority may encourage some car users to switch to public transport so reducing car usage.

8 Improvements in public transport services

For a public transport service to attract people out of their cars it must be
convenient, accessible, comfortable, safe (e.g. for women at night) and efficient (e.g. reliable and with minimal waiting time). Improved facilities at public transport stops (e.g. pre-payment of fares) can help avoid congestion and delay at boarding stops. Cheap, even subsidised, fares help. It is estimated that a 10 per cent improvement in public transport services can reduce car use by 2 per cent [2,15]. In Manchester, UK, a light rail system opened in 1992 and patronage increased by over 50 per cent compared with the original suburban rail lines which now form part of the light rail system, but car trips on the parallel roads decreased by only 5 per cent at peak times [17].

Light rail systems (trams) have an advantage over buses (unless electric) operating in pedestrian streets in that no exhaust emissions are emitted. Even so, guided buses can incorporate some of the advantages of a light rail system. Guided bus systems use conventional buses, with normal road wheels, which are guided using small guide wheels running against a shallow kerb. An advantage of the guided bus is its ability to run normally on conventional roads and to use guideways on fast arterial routes with heavy traffic. Several European cities have recently introduced (e.g. Leeds, UK) or are intending to introduce guided buses while Essen, Germany, operates the longest running system, introduced in 1980.

Bus lanes are the most common means of enabling buses to operate reliably and at higher speeds than they would in congested traffic, and so cut journey times. However, rarely is more than 5 per cent of bus route networks protected by bus lanes [15]. Bus lanes can reduce bus emissions during peak periods from between 20% [10,15] and 35% [9]. Bus-only streets can reduce times by 50% and bus emissions by 60% compared with mixed traffic operations [10,15].

Buses can be the cause of air quality problems in some situations, particularly along semi-pedestrianised streets, and especially if the buses are old and their engines inefficient. Leiden, The Netherlands, intends to halve the number of buses in its main shopping street by diverting the buses along other routes, so reducing CO and NO\textsubscript{2} levels by 5 per cent. An increasing number of cities are likely to take similar action, especially over concern for inefficient diesel-powered buses producing high PM\textsubscript{10} concentrations.

Park and ride schemes offer secure and free (or inexpensive) parking at a site on the outskirts of the city from which frequent and fast public transport services (bus, rail) operate to the city centre. Oxford was the first city in UK in 1973 to introduce a Park and Ride scheme. It consists of four sites located at the outskirts of the city offering 4000 car parking spaces from which frequent buses run to and from the city centre. In 1993, a survey of vehicles passing by the four sites found that were attracting on average 18.5 per cent of the morning traffic peak flow. An unwelcome effect of Park and Ride schemes is that the free and available parking as well as frequent bus services may encourage some people to drive by car to these sites who would otherwise use public transport to go to the city centre. A survey in Oxford indicated that 25 per cent of users would switch to public transport for their entire journeys if Park and Ride did not exist. Expanding the number of sites and parking capacity of the Park and Ride scheme, as well as introducing a daytime traffic restricted zone in central
Oxford, form part of a package of 90 individual traffic management measures being introduced in Oxford over a five year period (completion 1998). The Oxford Transport Strategy aims to reduce car use from 45% to 32% by increasing use of buses from 34 to 36 per cent, Park and Ride from 5 to 11 per cent, rail from 3 to 5 per cent, and cycling from 13 to 16 per cent [11,18,19].

Improvements to public transport are not usually sufficient on their own to reduce significantly the use of cars in city centres. Public transport improvement must be accompanied by car restraint measures such that use of the car is made less attractive and convenient than using public transport for some journeys.

9 Cycling

Many car journeys are relatively short. In the Netherlands, 37 per cent of car trips are less than 5 km and 55 per cent less than 7.5 km; both are considered to be cycling distances. At those distances, car use is often inefficient: travel time is not much shorter than using a bicycle in cities. Since short journeys generate relatively high emissions because the engine and catalytic converter have not warmed to their optimum operating efficiency, then cycling (or walking) can lead to disproportionately higher savings in emissions. For a small Dutch city of 150,000 population such as Apeldoorn which experiences 42,000 daily car movements, the replacement of car trips less than 5 km (about 25 per cent of total car trips) by cycling is estimated to reduce VOCs in the inner city by 14 per cent and across the city by 6 per cent [20]. Other analyses of the impact of replacing short car journeys by cycling suggest that local pollution levels within cities could be reduced by up to 17 per cent [21].

10 Conclusion

A wide range of traffic management measures are being implemented in European cities in an attempt to reduce traffic emissions and improve air quality. Many more monitoring and modelling assessments of their air quality impacts are needed in order to quantify how effective each measure can be in a range of urban settings. One of the problems facing researchers undertaking such assessments is that it is rare for one measure to be implemented on its own, rather a combination of complementary measures is introduced.

References

2. OECD. Road Transport Research: Congestion Control and Demand Management, OECD, Paris, 1994
Air Pollution Modelling, Monitoring and Management


17. Jones, P. *Daily Motorised Mobility: Can it be reduced or transferred to other modes?* Report prepared for ECMT 102nd Round Table, Paris, 1996.


