TRANSPORT and HEALTH in LONDON

a Report for the DEPARTMENT of HEALTH

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October 1999

CONCLUSIONS and EXECUTIVE SUMMARY

This report reviews the literature on the relationship between transport in London and the health of Londoners and thus its impact on health services in London. It does not comment on the wider impacts that traffic in London may have in contributing to the greenhouse effect or to acid rain. However in this respect it should be noted that national road traffic is not the main source of these pollutants contributing about 22% of CO_2 and only 2% of SO_2.

We have set out some firm conclusions in the following paragraphs. However, we recognise that uncertainty surrounds these conclusions. This was commissioned as a limited-scale, initial investigation and there are bound to be important sources that we are not aware of. There is a fair quantity of data available but it is not easy to deduce unambiguous conclusions from it. There is much variability in the phenomena being observed at the national level and the data is inevitably less decisive in relation to London, which has special characteristics, yet is a vast geographical area. Further, circumstances in London are changing quickly and this compounds the difficulties of accurate observation. As we report, where careful statistical work has been carried out in various parts of the world it has proved difficult to make estimates with a high degree of confidence. Much work remains to be done to test, reject or confirm the conclusions we set out here.

As far as London is concerned we draw the following conclusions:

- Public opinion is strongly of the view that traffic congestion and air pollution remain major problems in London and that traffic-generated air pollution damages their health

- Central government, its agencies and local government actively promote atmospheric pollution as a major health problem in London

- The level of toxic vehicle emissions is falling both nationally and in London. In London it is falling particularly rapidly, as a result of the introduction of catalytic exhaust gas converters in 1992, particle traps, improved engine technology, improved fuels and tax incentives. These improvements are set to continue in spite of national traffic growth, which is not matched in London itself.

  Continued efforts to reduce particulate emissions remain worthwhile, and can be achieved by the enforcement of existing legislation. A large proportion of this kind of pollution comes from a small proportion of the vehicles

- London is now one of the world's least air-polluted megacities (over 10m inhabitants) according to WHO and UNEP standards. It is in advance of New York and Tokyo and Los Angeles, which has particular geographic and meteorological problems that cause the concentration of atmospheric pollution.

- Government and its agencies could promote London as an essentially healthy city from the point of view of atmospheric pollution. Smoggy London ceased to exist in the 1950's and traffic emissions have diminished rapidly in the 1990's. On the other hand London can not be promoted as a city free of filth, rubbish and litter.

- The DoH COMEAP discounts the health effects of all but three traffic related pollutants: SO_2, particulates and ozone. These outcomes can be summarised as follows:

  - Lead emission from traffic has been almost eliminated.
  - Carbon monoxide from traffic (as opposed to smoking) is not a health problem in the concentrations normally encountered in London.
  - Ozone levels are lower in London than in most other parts of the country.
  - In early to mid 1990's traffic was responsible for over 20% of the SO_2, but measurements in Central London indicate that this had fallen substantially by 1998.
  - Similarly, traffic used to be responsible for over 75% of particulates, but there appears to have been a dramatic fall since 1996.

  The attributable additional costs to the DoH of these factors in the demand for additional services are small.

- In 1998 the costs to the NHS directly attributable to traffic in London were of the order of:

  Accidents £ 94m about 1 50th of the London NHS medical budget
  Pollution £ 7m about 1 600th of the London NHS medical budget

- In the international literature, where adverse health effects have been identified the uncertainty around the 'damage' or 'cost' estimates of emissions is typically large. The high degree of uncertainty is due to an absence of reliable data and the variability of circumstances. Where authors have reported 'best' estimates of the external costs associated with road transport emissions these are often small.

- The efforts now in progress at national and local level to introduce and attain National Air Quality Standards and to put in place Low Emission Zones do not appear to have been given a justification on grounds of saved health costs. They may not be justified on grounds of the avoidance

of the occasional discomfort of air quality incidents.

- The economic basis of the levels set for National Air Quality Standards should be scrutinised, with reference to the estimated benefits and with full attention to costs of compliance borne by individuals and the local economy. The significance of exceedences of such artificial standards on health is not evident, except in the promotion of adverse publicity

- The international literature suggests that emission levels and their costs vary quite substantially by vehicle type, fuel type, location of use and age. There is some evidence that targeting specific vehicle types and ages could significantly reduce emissions. The most damaging pollutant from a health point of view is probably particulates – often generated by old design or badly maintained diesel engines – produced in urban areas.

- Continuing efforts should be made to reduce atmospheric pollution from particulate matter and existing measures should be enforced. This may be justified on the basis of reduced health risk but possibly not on the basis of saved health costs.

- There may be evidence that particulates, especially $PM_{2.5}$, can cause damage to health in the long term. The reductions in particulate emissions now in train are wholly beneficial but they will not necessarily reverse the damage caused in previous decades.

- Lead can now be disregarded as a health threat and the history of its elimination is an illustration of how a mixture of fiscal incentive and appropriate physical regulation can stimulate rapid change in behaviour. This experience and success in reducing particulates to date both point towards means for achieving more in this area.

- Better quality diesel fuels have made a contribution in the past and continued attention to the fuels used is warranted – including consideration of fundamental changes to new kinds of fuel.

- Traffic reduction in London will probably only be justified on the basis of the non-health costs and benefits. Few traffic reduction measures are justifiable on health grounds.

- For London, congestion charging, if it is implemented by the elected Assembly, is likely to have a more noticeable impact on local traffic volumes than fuel-price based instruments. The further effect on air quality would probably be small and this is also true of other traffic management measures – even though they may be highly beneficial for other reasons.

- Even though the UK has a good comparative record on traffic accidents, there should be concern that the numbers of some types of accident (cycle and car) in London are currently rising.

- However worthwhile improvements to the health of individuals would be achieved by the promotion of a modal shift from the use of the car to walking or cycling, especially if this can be achieved without an undue increase in the numbers of road traffic accidents.

A 1 ATTITUDES and CONTEXT

Introduction

A recent document published by the Environment Agency [1] (an official body), concerning an exercise to create a "Greenprint for London" has the following headline assertions on its front cover

> *The number of cars on London's roads will double over the next 25 years. Road transport is currently responsible for 90% of London's air pollution.*

We offer evidence in this report that both of these statements are highly misleading: a reasonable person would be unlikely to draw these conclusions.

This example illustrates several features of the debate on the relationships between health and transport in London.

First, London is quite different from the nation as a whole. It may be reasonable to forecast continued rapid traffic growth at the national level, but not in London where traffic is growing slowly, or not at all. London itself is vast and heterogeneous. The outer areas of London behave in a more similar way to the rest of the nation than does the centre. Policies must be addressed to the circumstances of the particular locality.

Second, some individuals and organisations feel able to be cavalier with the facts in order to make a case. Transport is only one of several sources for air pollution and it is rarely responsible for anything like 90% of the total exposure

Third, the air pollution situation in London is improving rapidly. Data and attitudes valid only three or four years ago are not a reliable guide to the current situation. London now has the better air quality than most major world cites, partly as a result of successful mitigation action and partly because it is blessed with favourable climatic conditions. Some pollutants that are a problem in other places do not exist in troublesome concentrations in London. Some official bodies are not modifying their attitudes to reflect these improvements.

[1] Creating a Greenprint for London: The Environment Agency

Fourth, there is an element of unfounded fear amongst the general London population. There is a presumption that air pollutants are damaging to health. Some are, but several of the officially recorded pollutants are of little consequence in London, in practice. An example of pre-emptive, precautionary judgement by official institutions is provided by the South East Institute of Public Health (SEIPH) [2].

SEIPH gathers data from monitoring stations throughout London taking some 140 measurements of various pollutant levels per day at several locations. It then grades the daily readings according to thresholds, as low, moderate or high. These results are then collated as pollution level reports for London as a whole, on the simple basis that if any one of the 140 daily readings should exceed the threshold then the London wide result is recorded as exceeding the threshold.

By way of an example, in the seven days from 1-7 October 1999 SEIPH recorded and published the following results.

day	*low*	*moderate*	*high*	*grade*
1	*136*	*4*	*0*	*moderate*
2	*134*	*6*	*0*	*moderate*
3	*140*	*0*	*0*	*low*
4	*140*	*0*	*0*	*low*
5	*140*	*0*	*0*	*low*
6	*137*	*3*	*0*	*moderate*
7	*137*	*3*	*0*	*moderate*
total	*964*	*16*	*0*	
	readings	*1.7%*		*report 57%*

16 out of a possible 980 readings exceeded the threshold during the seven day period. However, on 4 days out of seven SEIPH reported that that the level of pollution was "moderate" as opposed to "low". Thus SEIPH risks over exaggerating the pollution problem in the data they record and disseminate.

Fifth, there are many aspects of the relationship between health and transport, but the alleged connection between transport-generated air pollution and health seems to be the one that most concerns the general public and many officials. For this reason we have given this aspect of the subject particular attention in this report.

[2]SEIPH London Air Quality Network www.seiph.umds.ac.uk

> The actual consequences in terms of potential economic damage entailed in following through actions to ensure pollution levels conform to the stringent air quality standards do not seem to have been fully considered. Nor are the positive health effects (which may in fact be minute) of achieving such conformity set in the balance.
>
> Air quality standards have been set with inadequate attention to the benefits of meeting them and there is a risk that the ill-considered costs imposed by the authorities seeking to secure compliance will greatly exceed any benefits. The social costs of compliance with regulations that impede movement should not be underestimated.
>
> The risk is that these costs would cause more damage to quality of life, and health in particular, than the pollutants they are designed to eliminate. These effects for the health of citizens have the potential to far exceed the health benefits that may accrue from improved air quality arising from traffic reduction.

This report reviews current evidence on some of these issues. It is hoped that these findings may assist in arriving at a more reasoned balance in the argument. Transport policy can make a contribution to the health of Londoners, but that will require a focused attack on a few specific problems, together with a recognition that physical exercise is a realistic alternative to motorised transport for many trips in and around London.

More exercise would be effective in mitigating the major causes of ill health.

The effects of transport on health: a classification.

In its briefing paper[3] for Health Professionals and local authorities subsequent to the recent Integrated Transport White Paper [4], the Health Education Authority classifies the effects of transport on health as follows:

Health Promoting
- *Enabling Access to*
  - *employment*
  - *shops*
  - *recreation*
  - *social support networks*
  - *health services*
  - *countryside*
- *Recreation*
- *Physical activity*

Health Damaging
- *Traffic Injuries*
- *Pollution*
  - *particulate matter*
  - *nitrogen oxides*
  - *carbon monoxide*
  - *hydrocarbons*
  - *ozone*
  - *lead*
  - *benzene*
- *Noise and Vibration*
- *Stress and Anxiety*
- *Danger*

Loss of land and planning blight
Severance of communities by roads

This advice from a government body does (in an aside) state that not all transport impacts have negative effects on health but it clearly makes and repeats a generally held assumption that transport has much greater adverse effects, particularly from pollution, on the nation’s health than positive benefits.

It is hardly surprising that this view is held when the DETR [5] in its consultation paper states:

> *Road Traffic Reduction Act 1997*
>
> *Part 4 - RELATIONSHIP OF TARGETS TO AIR QUALITY OBJECTIVES*
>
> *56 The Environment Act 1995 included provisions which required the management and improvement of air quality in the United Kingdom. It also laid the foundations for a nation-wide system of local air quality management, in which local authorities are obliged to review and assess the quality of air in their areas, and to take action where air quality objectives are breached or at risk of being breached. The National Air Quality Strategy sets out the approach required by the Environment Act.*

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[3] Transport and Health: Health Education Authority 1998
[4] A New deal for Transport: better for everyone - the Government White Paper on the Future of Transport: DETR 1998
[5] DETR Road Traffic Reduction Act 1997: Draft Guidance to Local Traffic Authorities: Part 4, paras 56 - 59

57 The Strategy includes health-based objectives for pollutants of most concern - nitrogen dioxide, particles, ozone, sulphur dioxide, carbon monoxide, lead, benzene, and 1,3 butadiene. One of the main purposes of the strategy is that these objectives should be met throughout the UK by 2005. Major reductions in pollutant levels will result from national measures such as tougher vehicle and fuel standards; new EC proposals for revised vehicle and fuel standards, to take effect from 2000, will achieve overall emissions reductions of around 50% on 1995 levels by the year 2005.

58 These measures are reinforced by the use of fiscal incentives; lower duty on alternative fuels, and a commitment to an increase of at least 6% above inflation each year on road fuel duties. However, in some areas these will not be sufficient for the objectives to be achieved. Local authorities will be required to review and assess the air quality in their area and if it appears that the objectives will not be met by 2005 designate an Air Quality Management Area. They will then be required to develop a local action plan which outlines measures to reduce pollution levels.

59 The Government has issued guidance to local authorities on air quality and land use planning, air quality and traffic management, local authority action plans and reviewing and assessing air quality. Clearly, local authorities will need to ensure that any traffic reduction targets, and measures designed to achieve them, are fully integrated with their strategy on air quality. The relationship between the two should be clearly set out in TPP submissions."

Here, in legislation the government is clearly making the linkage between air quality and health as the primary rationale for traffic reduction.

In its recent report the DETR [6] responds to the Committee on the Medical Effects of Air Pollutants (COMEAP) report as follows:

Air quality

11. People are increasingly concerned about the impact that air pollution has on health, and on the urban and rural environment. This concern is also backed up increasing scientific evidence. And whilst there is no evidence that healthy individuals are likely to experience acute health effects at typical pollution levels experienced in the UK, a major report published by the Department of Health last year noted that the deaths of between 12,000 and 24,000 vulnerable people are bought forward every year by the effects of air pollution from all sources.

[6] DETR: The Environmental Impacts of Road Vehicles in Use Air Quality, Climate Change and Noise Pollution

Air quality and health. A key report published in January 1998 by the independent expert Committee on the Medical Effects of Air Pollutants (COMEAP) for the Department of Health was the first official attempt to quantify the impact of short term air pollution on the health of people living in the UK. It suggested that the deaths of between 12,000 and 24,000 vulnerable people may be brought forward each year and that between 14,000 and 24,000 hospital admissions and readmissions may also result from poor air quality. These effects are attributed to three of the eight pollutants for which objectives have been set in the National Air Quality Strategy (discussed below): particulate matter (PM_{10}), (which is estimated to bring forward 8,100 deaths annually), sulphur dioxide (3,500 deaths) and ozone (from 700 to 12,500 deaths).

The report only tried to quantify the short term effects of these three pollutants. It did not quantify the long term chronic impacts, nor cover the other emissions associated with transport such as benzene or 1,3 butadiene, which are known carcinogens, or lead which is associated with harming cognitive development in children, as it was considered inappropriate to quantity health effects of these pollutants in this way. More information about the health effects of different pollutants can be found in the National Air Quality Strategy.

Clearly, the levels of these pollutants which give rise to health effects are not solely due to road transport, even in the most congested areas. For instance, emissions of sulphur dioxide (SO_2) are principally produced by fossil-fuelled power stations. However, vehicles make a significant contribution to local air pollution, and this proportion maybe even higher when pollution levels are very high.

However this reaction fails to recognise the important comment made by COMEAP [7]:

1.12 It is stressed that the effects on mortality have not been fully quantified. Many of the deaths associated with days of higher air pollution are in the elderly and the sick. Episodes of cold weather and epidemics of the common cold hasten the deaths of such people and it seems likely that air pollutants could act in a similar manner, hastening death by a few days or weeks. If this is the major effect, the impact of air pollution episodes on mortality will be relatively small, but we have been unable to establish the extent by which the time of death has been altered.

An adverse relationship between atmospheric pollution derived from traffic and health seems to be considered as self evident rather than being a matter that could be open to question, even when, as we note below, in reality air quality in London is improving rapidly and when even two years ago air quality may have had only a minor impact on health.

[7]COMEAP DoH: Committee on the Medical effects of Air Pollution: Quantification of the Effects of Air Pollution on Health in the United Kingdom

A 2 PUBLIC OPINION

In November 1998, the Kings Fund and the Evening Standard commissioned MORI to undertake a poll of Londoners [8] with regard to their views on the most significant matters relating to their health as citizens.

The interviewees considered that London was generally an unhealthy place to live in, more so when compared with other parts of the country and that the situation was likely to get worse not better.

The survey also asked the interviewees to prioritise the actions that the new Mayor of London might take in respect of these matters. The result gave a clear indication of publicly held views and the priorities for the new London Government. The results were then included in a King's Fund Report [9] along with other commentary on matters affecting the health of Londoners.

In this respect the poll asked two key questions which were answered as follows:

Q7 Which 3 things on this list do you think have the most effect on your health living in London today?

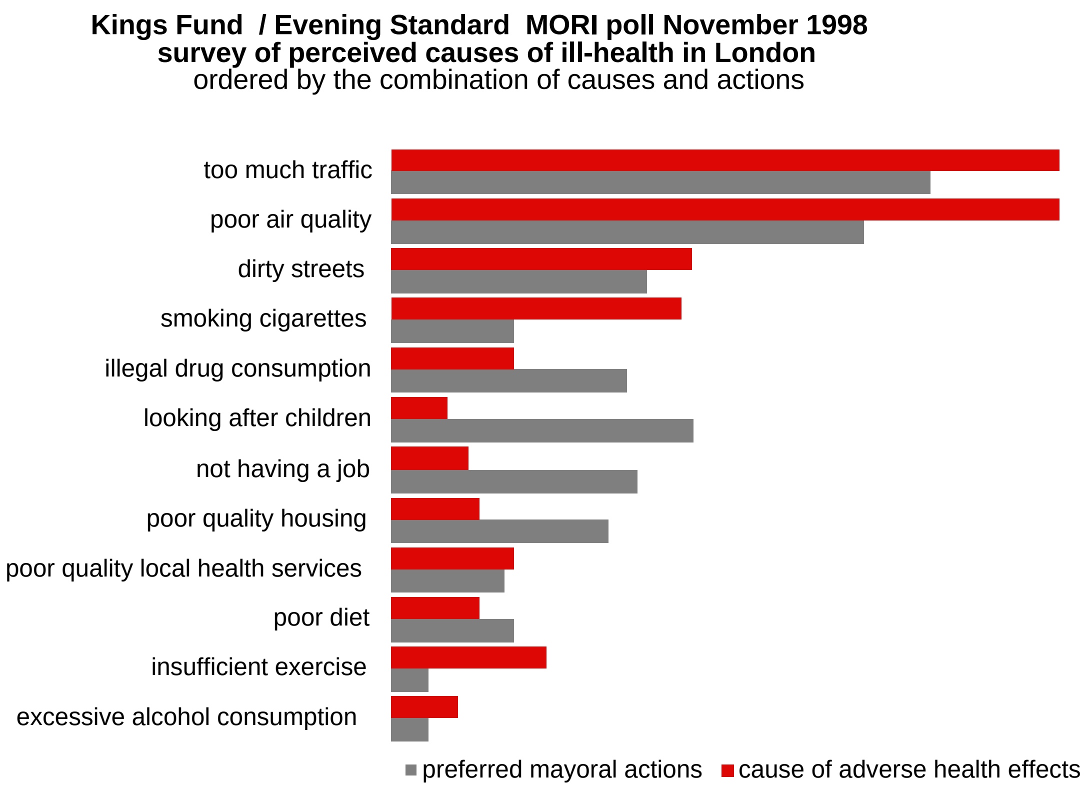
	%
Poor air quality	*60*
Too much traffic	*60*
Dirty streets (e.g. litter and dog mess)	*27*
Smoking cigarettes	*26*
Having too stressful a job	*19*
Not enough money/low income	*16*
Illegal drug consumption	*14*
Insufficient exercise	*14*
Poor quality local health services	*11*
Poor quality housing	*9*
Not having a job	*7*
Excessive alcohol consumption	*6*
Looking after children	*5*
Poor diet	*8*
None of these	*1*
Don't know	*1*

[8] MORI Social Research for the King's Fund and the Evening Standard: Survey of Londoners November 1998.
[9] Health and the London Mayor: King's Fund Public Health Series- 1999

Q8 The London Mayor is going to be responsible, amongst other things, for promoting the health of Londoners. Once he or she is elected, what should be their top 3 priorities for change to make London a healthier place to live?

	%
Reducing traffic	*57*
Improving air quality	*50*
Improving child care facilities	*32*
Cleaner streets (e.g. reduce litter and dog..mess)	*27*
Reducing unemployment	*26*
Reducing illegal drug consumption	*25*
Improving housing	*23*
Promoting healthy eating	*13*
Reducing cigarette smoking	*13*
Improving the quality of local health services	*12*
Promoting health and safety in the workplace	*6*
Reducing alcohol consumption	*4*
Promoting exercise	*4*
None of these	*0*
Don't know	*1*

Twelve items in these questions matched the perceived cause of ill health with potential mayoral action. The chart below collates and summarises those results and orders them by combined priority:



The chart clearly shows that the Londoners interviewed place at the top of their priority list as a danger to their health excessive traffic and in addition consider that the air quality in London is very detrimental to their health.

Interviewees from Outer London were marginally more concerned about traffic than those in Inner London. It is as if the congestion consequences of living in the suburbs are much less acceptable than those that are expected when living in the Metropolis itself.

Following immediately on from concern about traffic and air quality is concern for the cleanliness of London's streets: this indeed could constitute a direct health risk from the encouragement of rats and other disease carrying vermin. Only then follows smoking and the use illegal drugs. The direct causes of ill-health in London, such as excessive alcohol consumption, insufficient exercise, poor diet, etc. come low in their list of priorities.

These attitudes were also found in London household interviews conducted in 1999 for the independent Working Group on congestion charging in London (ROCOL). 89% said that there was "too much traffic" in London, and of these 49% said that "air pollution" was a problem caused by traffic. After "slow car journey times" this was by far the most commonly identified problem, with "noise pollution" next at 22%.

Whether they are in error or not, it is certainly the perception of Londoners that excessive traffic and poor air quality are prime factors and do constitute major health risks. It is as if the legend of "foggy London" lives on, in spite of evidence to the contrary. It certainly was true 45 - 60 or more years ago when the deadly "peasouper" was a common event every winter. Since that time, the Clean Air Acts, the use of smokeless fuels and gas or oil for domestic and industrial heating have revolutionised the pollution facts.

In those intervening years it is certain that emissions from increasing traffic caused pollution problems in the late 1980 and early 1990's. The evidence now shows that with improving technologies (particularly catalytic exhaust converters first introduced in 1992) and the use of less-polluting fuels, rapidly permeating through the vehicle fleet that pollutant emissions from traffic are also rapidly diminishing.

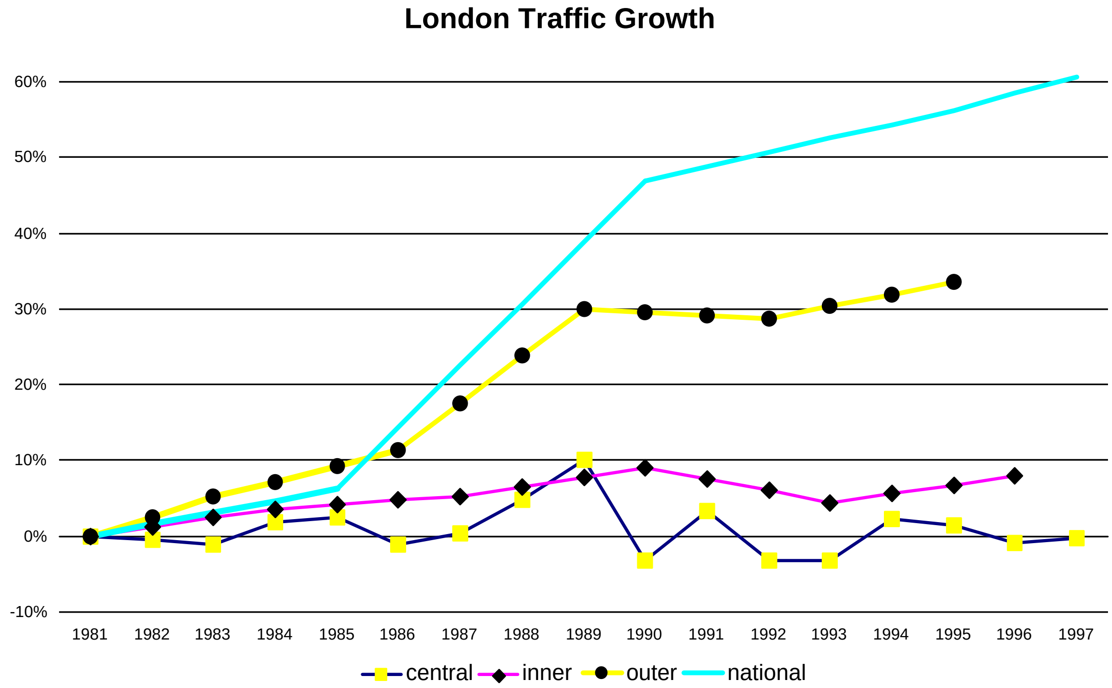
It seems that Public Opinion is entrenched. This is hardly surprising when it is clear from government legislation that a view of the direct relationship is widely held and strongly promoted by local and central government.

That does not mean to say that there is not still much to do in London. Certainly people have good reason to think the filthy smoke they often see coming from a bus, a taxi or a heavy goods vehicle must harm their health. It is still likely to be true that a small proportion of the vehicles (usually older diesel types) produce most of the adverse emissions from traffic.

However much more has to be done in opinion forming to persuade Londoners that in general they live in a much improved environment than earlier generations and that by tackling a certain limited numbers of polluters, which can be achieved by simply implementing existing legislation, that their health position vis a vis traffic can easily be improved even further.

A 3 LONDON TRAFFIC GROWTH

The chart below shows the traffic growth in London when compared with the National Traffic Index [10]. The measure is for crossings of London's central, inner and outer cordons [11]. It shows some fluctuations but essentially nil growth in traffic passing in and out of Central London since 1981. The Inner London cordon crossings grew by almost 10% up until 1990 but have essentially stabilised since. Crossings of the outer cordon grew by 30% between 1981 and 1992 but have since stabilised. These mainly represent commuting by car into the London area. However since 1981 the UK traffic index itself has grown by some 60%.



These findings are matched by the change in vehicle kilometres per annum driven in London which has risen from about 11.3 billion vehicle kilometres in 1987 to 13.8 billion vehicle kilometres in 1999 a rise of 1.2% compound over the period, as compared to a rise in national traffic of 3.0% compound over the same period.

Vehicle registrations in London have shown similar differentials with a rise of 6% since 1987 whereas the national average is close to a rise of 24% [12].

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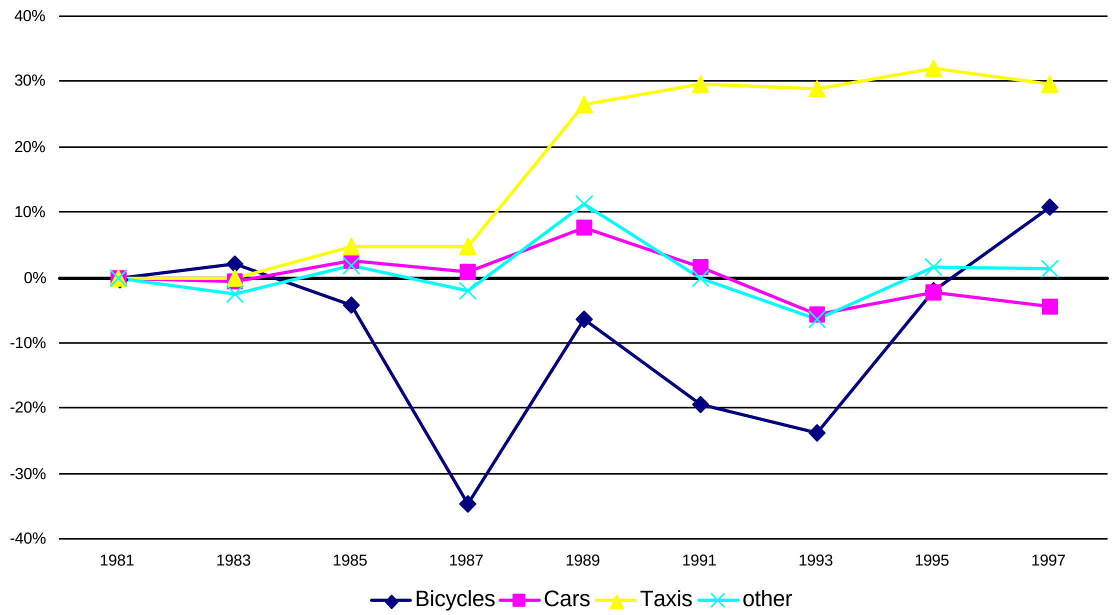
[10] National Traffic Index: source NETCEN / AA
[11] Focus on London 1999 Chapter 10
[12] Focus on London 1999 Chapter 10

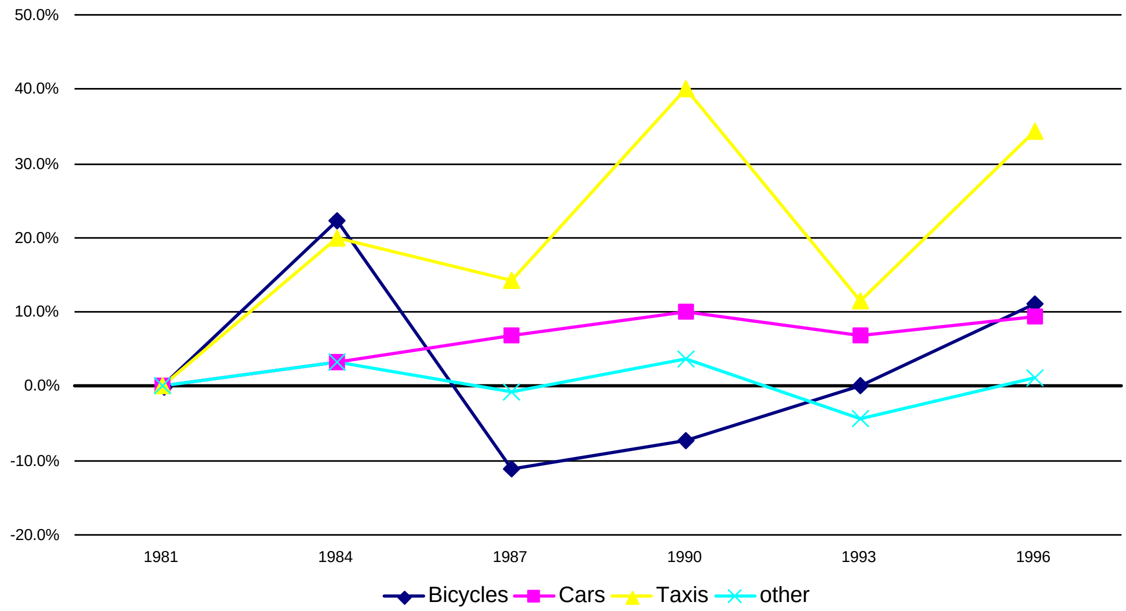
The following three graphs show the manner in which the use of different travel modes has changed over a similar period. Car, public transport, deliveries, etc. have remained stable over the period in Central London, on the other hand Taxi use has increased considerably.

Having fallen off to a great extent the use of bicycles is recently showing an increase. Inner London has seen stable car usage since 1990 and bicycle use is now recovering.

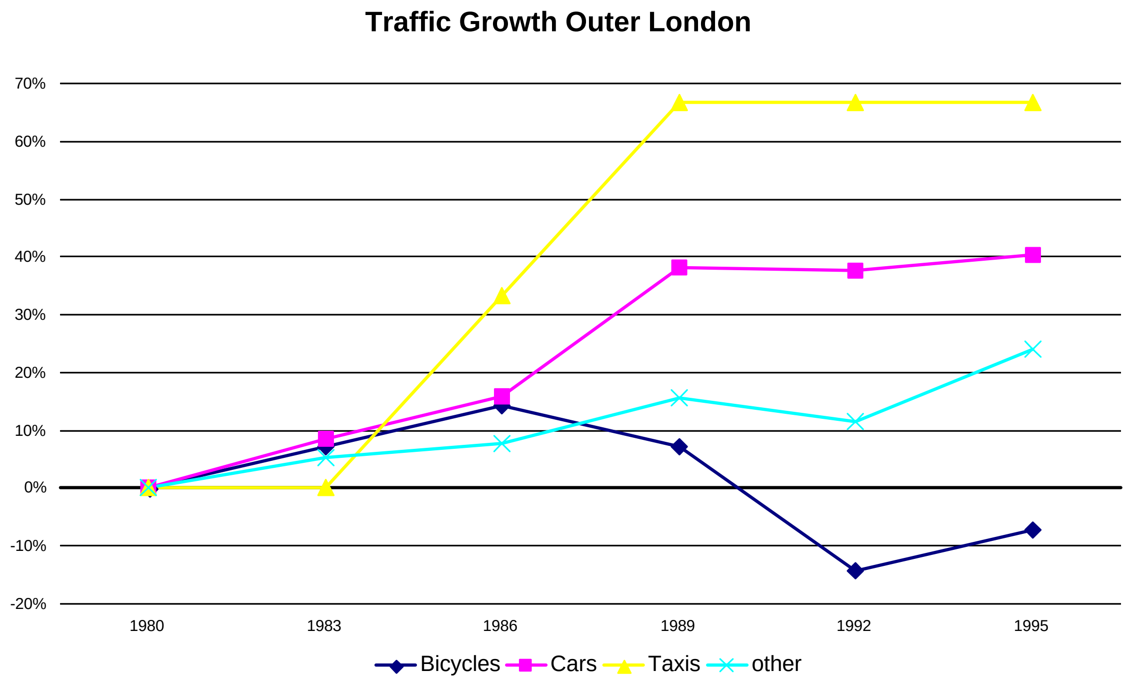
Traffic Growth Central London



Traffic Growth Inner London



For traffic crossing the outer London cordon (see over) car commuting grew till 1992 but has since stabilised and bicycle traffic is showing some increase.

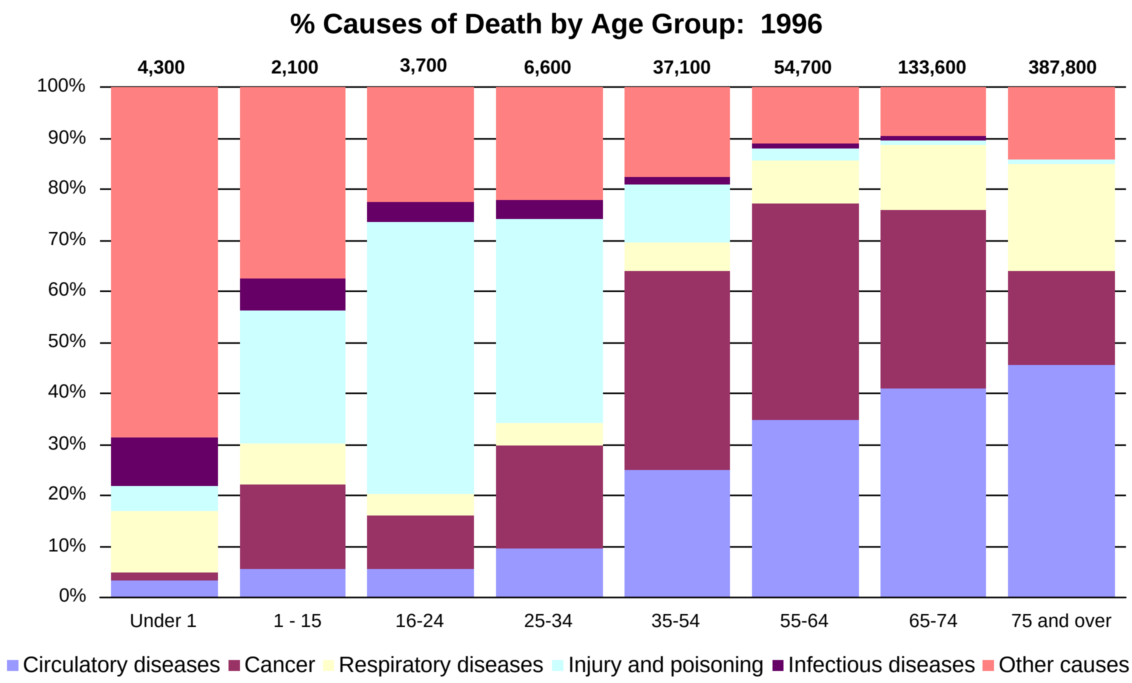


Traffic speed have generally reduced in the last 20 years [13] as follows:

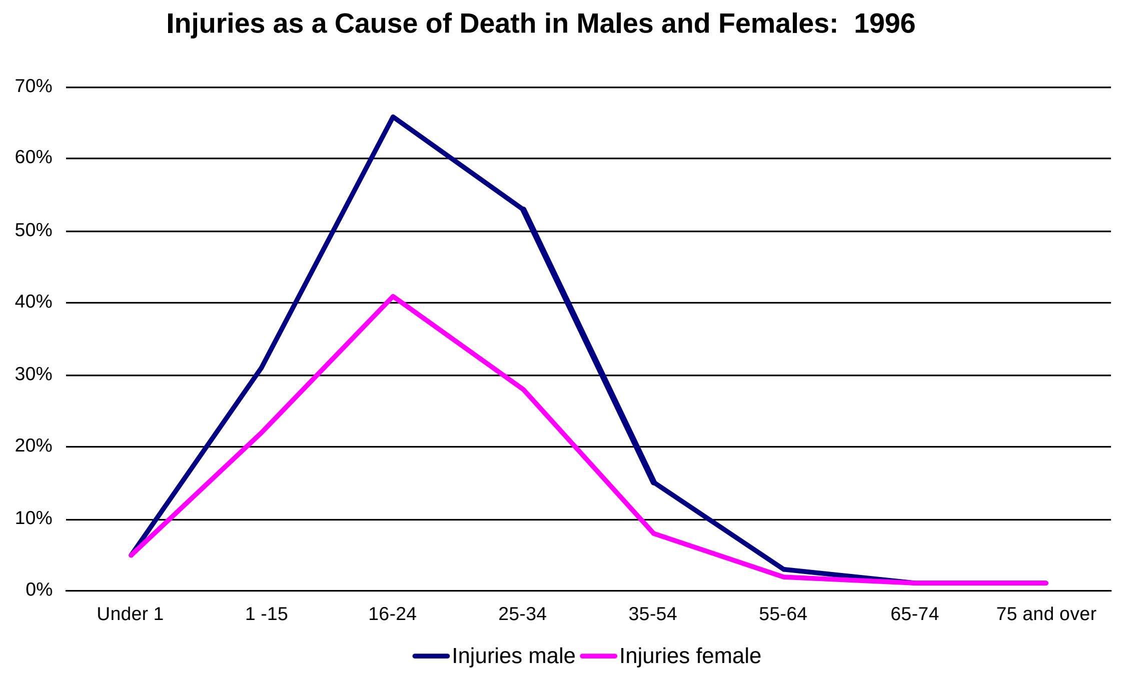
	1969	1996
central	12.5	10.1
inner	16.2	13.8
outer	23.0	19.5

[13]Focus on London 1999 Chapter 10

A 4 NATIONAL MORTALITY

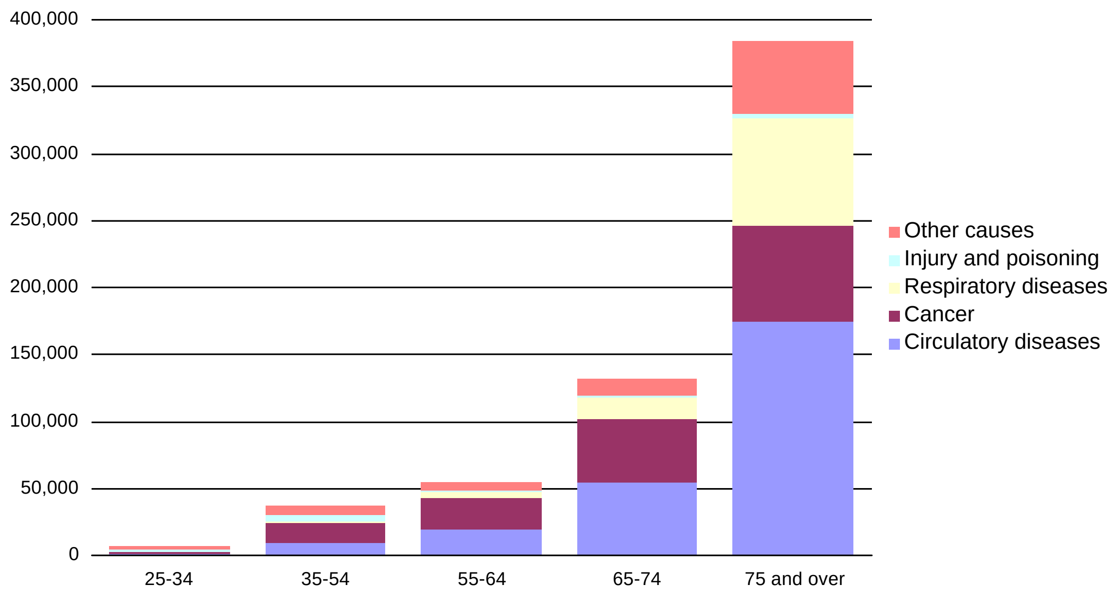


The chart above shows the absolute numbers of deaths in the population and how they are distributed by cause and age group [14]. It clearly shows the impact of injuries including traffic accidents as a cause of death in the three age groups 1 - 15, 16 - 24 and 25 - 34: but only 2.5% of all deaths occur at these ages. In the total population injuries only account for some 3% of all deaths. Almost twice as many males die from injury, particularly traffic injuries, as females.



[14] ONS Statbase

Causes of Death from the Age of 25: 1996



However when the absolute number of deaths are taken into account in older age groups circulatory diseases, (mainly heart disease and stroke) take over as the primary cause of deaths. The factors which advance these causes of deaths most significantly are likely to be smoking and poor physical fitness.

We have not investigated the corresponding statistics for London, but, on the assumption that the national patterns are repeated any actions within transport systems to improve these factors will markedly improve the health and longevity.

Of all deaths COMEAP was able to attribute about 0.5% to atmospheric pollution in 1998. These were occurring in the frail and elderly. Only a part of atmospheric pollution is caused by traffic (see later).

Professor D M Newbery [15] gives some comparative figures of years of life lost from different causes, referencing a French Academy of Sciences Report [16] as follows:

	comparative years of life lost
Smoking as a yardstick	*order of 1,000,000*
Passive Smoking	*order of 10,000*
Traffic Accidents (often affecting younger age groups)	*order of several 100,000s*
Air Pollution from Transport	
Direct Effects of Particulates	*order of 100s*
Longterm Carcinogenic Effects	*possibly of the order of about 1,000*

[15] Prof D M Newbury (1998) Fair payment from road users: a review of the evidence on social and environmental costs AA

[16] Academie des Sciences, (1996) pollution Atmospherique due au transport - Rapport d'etape l'Academie des Sciences

A 5 The RELATIONSHIP between TRAFFIC and HEALTH

A considerable body of work on the particular epidemiology of London has been undertaken at UCL in the Department of Epidemiology and Public Health.

Probably the most comprehensive report on the relationship between transport and health in London was prepared for the health of Londoners Project [17]. This sets out the implications of transport for health in London and suggests policy responses to make transport healthier. The report considers a variety of different health-related aspects of transport. These include:

- Accident rates
- Air and noise pollution
- Physical activity and the benefits of exercise induced through transport behaviour in preventing heart disease and improving mental health.
- Community severance created by heavy traffic flows in commercial and residential areas.

The report draws attention to the lack of a unified political authority for the planning and administration of London arguing that this had led to a lack of co-ordination and understanding of transport and its cost to health in London.

The report specifies three approaches required to make transport healthier:

- Ameliorate and reduce motor vehicle use through the imposition of traffic management measures.
- Enhance pedestrian and cyclist journeys by making improvements to the environment, safety, health education and by enhancing pedestrian and cyclist priority.
- Improve public transport

Ferguson and McCarthy [18] use publicly available data to describe various dimensions of environment and health in London. The report contains sections on transport and air quality. Their data show that over 200 people are killed on the roads in London each year and that higher rates of death and serious injury occur where there are greater car speeds (main arterial road routes) and in inner London where there is more traffic and more pedestrians.

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[17] Transport in London and the Implications for Health: The Health of Londoners Project: July 1996 for the East London and the City Health Authority: Professor M McCarthy, J Ferguson and N Söderland

[18] Ferguson J and McCarthy M (1999a) Environment and health in London. London: King's Fund

They also show that heart disease is a major cause of death and disability yet 20% of Londoners take no physical exercise at all. An increase in the proportion of Londoners undertaking walking or cycling trips would provide benefits through increased physical exercise. The report also shows that London's air is becoming less polluted, but it points out that pollution from road transport was rising.

This study has been supplemented more recently by Environment and Health Resource: Indicators for London [19] and Environment and Health in London [20]. These two documents contain essentially similar data but the latter presents them in an easily assimilated graphical format. Although this data was as up to date as possible when published, it was derived from a wide variety of sources and would benefit form continuous update: this comment equally applies to the report referenced above published in 1996.

It is thought that the matters addressed there are in a state of considerable of flux particularly due to following factors:

- the positive effects of existing pollution controls
- the upgrading of the vehicle fleet radically reducing exhaust emissions
- improvements in road safety.

In the future other factors might be:

- rapid demographic change in central London, with more people living centrally and commuting less
- the impact of improving telecommunication and e-commerce reducing the need for travel,

Continuously up to date information may well provide an even more balanced view of the current status of the position of traffic and health in London.

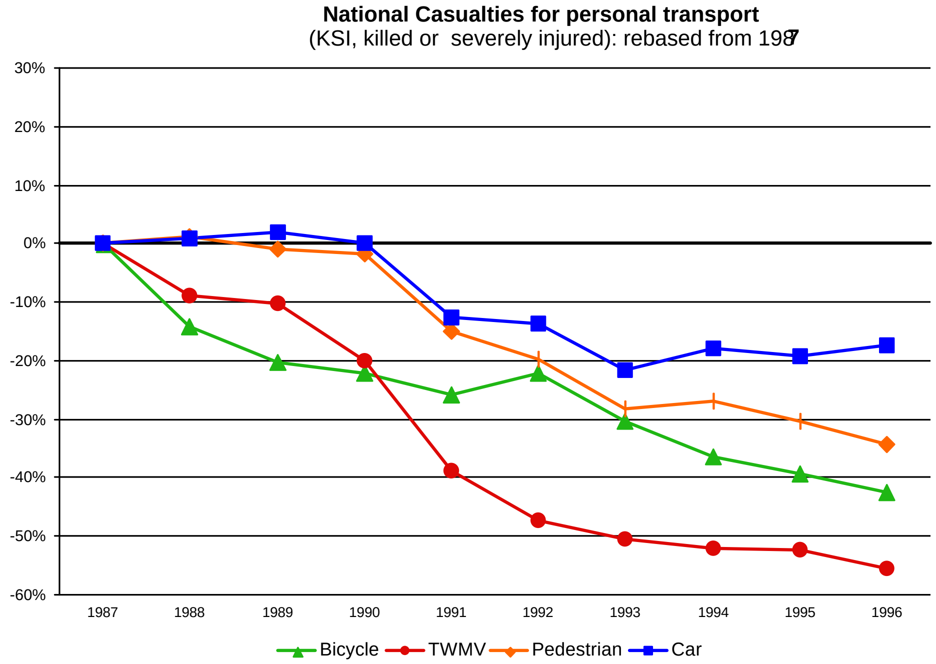
[19] Environment and Health Resource : Indicators for London UCL Department of Epidemiology and Public Health Professor M McCarthy, J Ferguson

[20] Environment and Health in London: Report to mark the Third European Ministerial Conference on Environment and Health and the Healthy Planet Forum London June 1999 Professor M McCarthy, J Ferguson Published by the King’s Fund

B 1 TRAFFIC ACCIDENTS

National figures for traffic accidents have seen steady improvement over the past 10 years [21].

Shown below are the national figures for personal transport modes (cars, motorbikes, bicycles and on foot) which account for about 94% (nationally), of all KSI (Killed or Seriously Injured) accidents



Figures for minor injuries are ignored because it is only KSI accidents that impose significant continuing loads on NHS hospital services. The burden of treatment of slight injuries presumably is more widely distributed, falling mainly on general practice.

It is likely that the diminution of bicycle accidents may largely be due to the reduction of bicycle trips rather than any increase in safety. The additional safety features in cars, reduction of drunk driving and the imposition of seat belt law have probably contributed to the reduction of car injuries but these effects may now be leveling out.

However by contrast when the same analysis is undertaken for accidents in London [22] a different and more troubling picture emerges. Only 91% of KSI casualties are attributable to the four personal transport modes in London.

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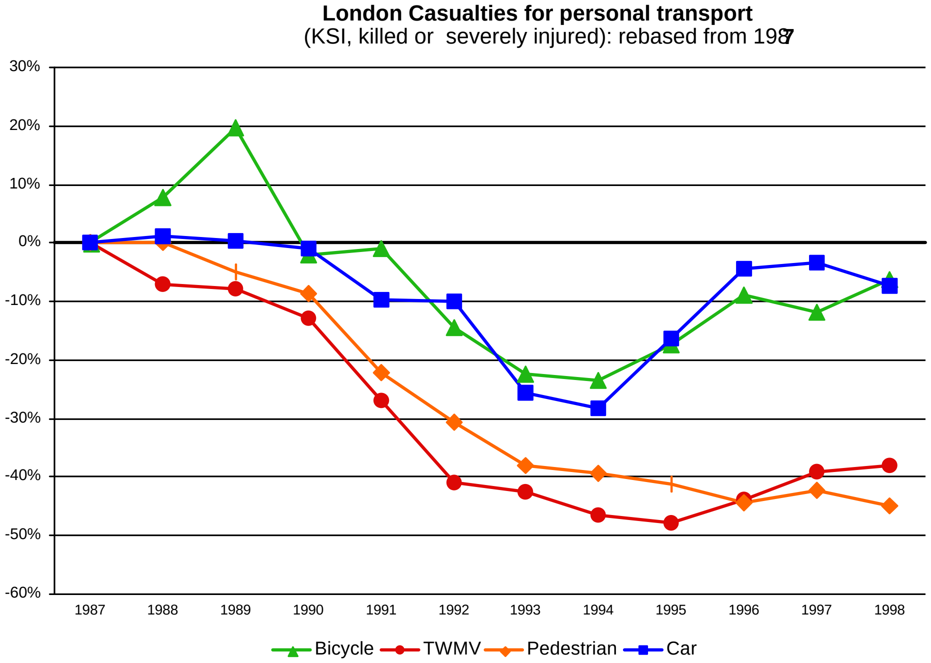
[21] DETR Transport Safety Consultative Paper 1999 Annex 1, Table A1.6 (data up to 1996)

[22] Data up to 1998 provided by J Devenport at the London Accident Analysis Unit (LAAU) of the London Research Centre.

Motor cycle casualty rates having fallen considerably are now rising again. Pedestrian casualty rates may have stopped their decline. Bicycle and Car casualty rates are returning to be close to the levels seen 10 years ago.



In spite of the public dismay at the rail crash at Paddington in October 1999, the other public modes of transport such as Air, Rail, Bus, Taxi, etc. give rise to very much smaller absolute numbers of actual casualties. Public modes of transport are intrinsically much safer than all personal forms of transport.

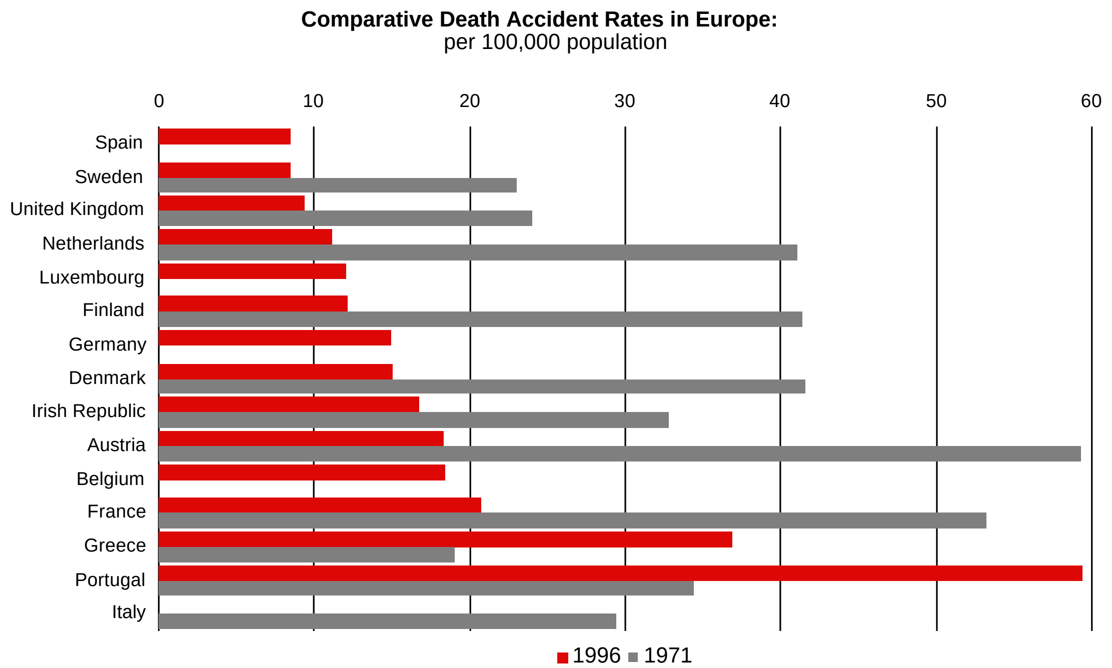
The risk factors by mode of the KSI casualty numbers in London in 1998 these were as follows:

KSI 1998	*casualties*	*risk by distance*	*risk by journeys*	*risk by time*
car	2694	1	1	1
foot	2022	16	13	1
bicycle	607	22	6	16
motor cycle	1001	35	30	31

Also included in the table above are the risk factors of the different modes of personal travel, normalised to the safest form personal transport, the car: for example, if 100 miles are travelled by car, there is 35 times less likelihood of having an accident than when travelling the same distance by motorbike.

However the tolerable risks that are accepted by public transport passengers are lower, both because safety is the responsibly of an external organisation, not the individual concerned and because the accidents when they do occur they are likely to affect greater numbers in a single incident and to receive much greater adverse publicity. If the KSI figure for the Paddington rail crash amounts to 150 (a high estimate for the seriously injured) that will represent about 2 % of the KSI count in London for the year or about a week's losses from road accidents.

B 1.1 INTERNATIONAL COMPARISON



The UK in comparison with other European countries has a reasonably good accident record. It is in the lowest three alongside Spain and Sweden [23]. In addition it has more than halved the death rate in the last 25 years.

[23] Road deaths EU comparisons: ONS Statbase

B 1.2 NHS COSTS of TRAFFIC CASUALTIES in LONDON

The approximate medical and ambulance costs of all accidents in London using cost data from DETR [24] and the LAAU figures [25] for 1998 are as follows:

severity	*number*	*unit value*	*total cost*[26]	*medical cost/unit*	*medical cost*
killed	221	£1,042,410	£230,37m	£4,470	£0.99m
injured	6,569	£124,610	£818,56m	£9,440	£62.01m
slight	38,272	£12,430	£475,720m	£780	£29.85m
overall	45,062		£1,524.65m		£92.85m

Thus the costs to the NHS of traffic accidents in London amounts to about 2.1% of the total costs of NHS medical provision in London of about £4,242m, see Annex 1.

Of this sum 2/3 rds of the cost fall on the hospital service and the other third of the burden is distributed throughout the family practice network

[24] DETR Transport and the Regions: Highways Economic Note No.1 1997 - Table 3
[25] Data up to 1998 provided by J Devenport at the London Accident Analysis Unit (LAAU) of the London Research Centre.
[26] This sum includes the valuation of loss of statistical lives, costs of lost output, police costs, insurance admin and damage to property as well as the medical and ambulance costs separated out above as direct costs to the health service.

C 1 ATMOSPHERIC POLLUTION: LONDON in CONTEXT

The ARIC [27] Fact Sheet 11 provides a comparative chart for pollution in World megacities based on World Health Organisation (WHO) / United Nations Environmental Program (UNEP) comparative guidelines.

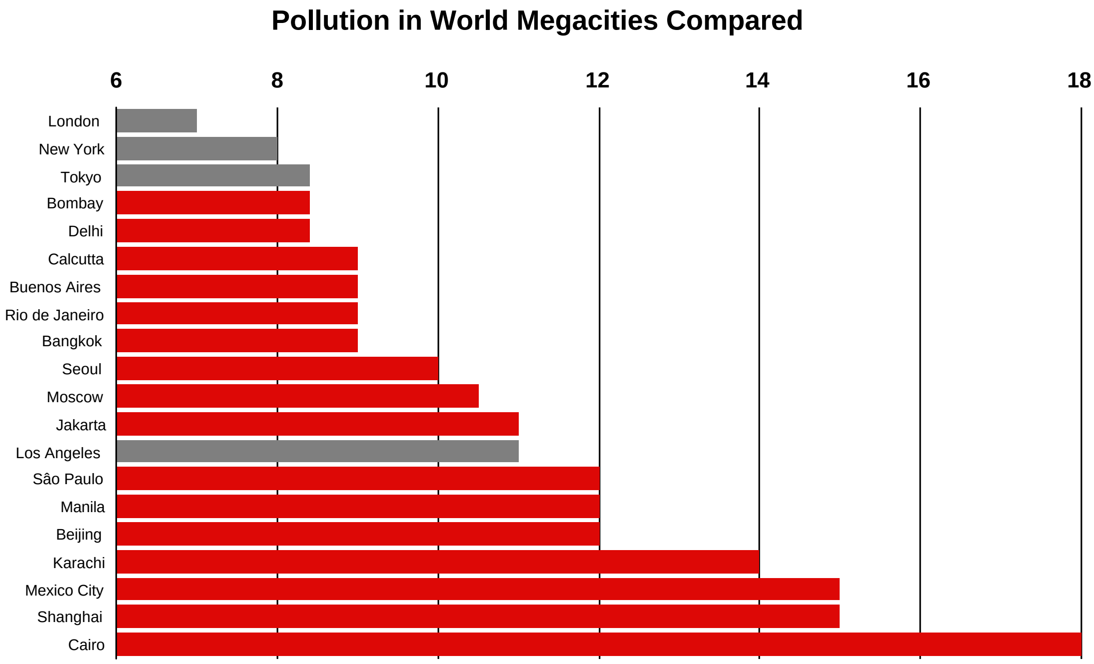
Accordingly a comparative scoring mechanism for the six commonly agreed pollutants Sulphur Dioxide, Solid Particulate Matter (SPM), Lead, Carbon Monoxide, Nitrous Oxide and Ozone has been established:

score

1 low pollution: WHO guidelines are normally met (short term guidelines exceeded occasionally)

2 moderate problem: WHO guidelines exceeded by up to a factor of 2

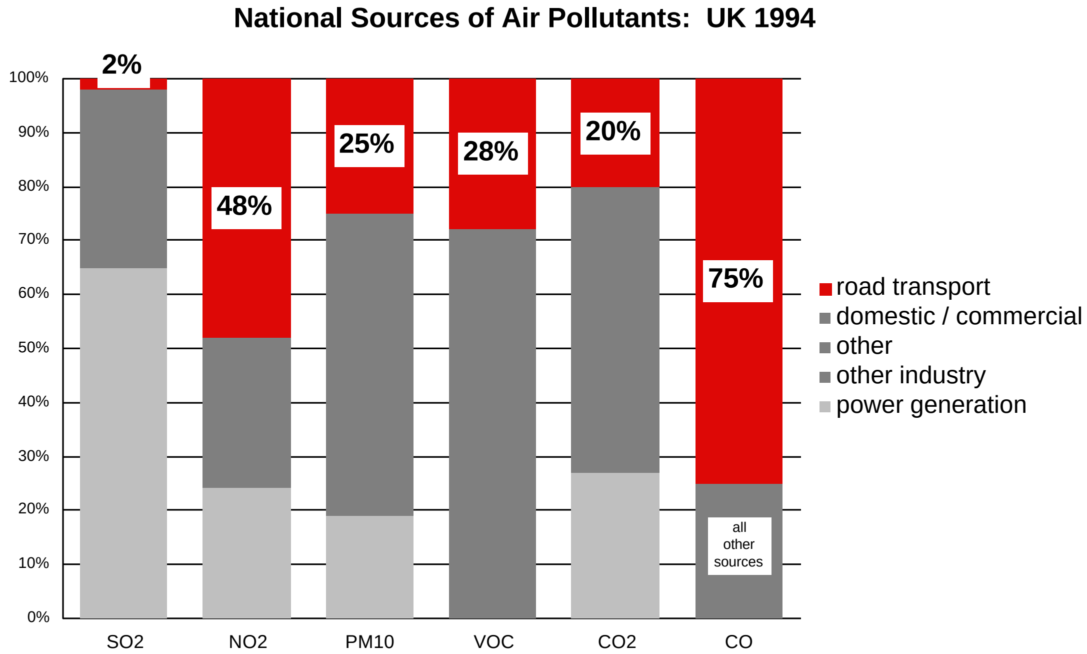
3 serious pollution problem: WHO guidelines often exceeded by a factor of 2 or more



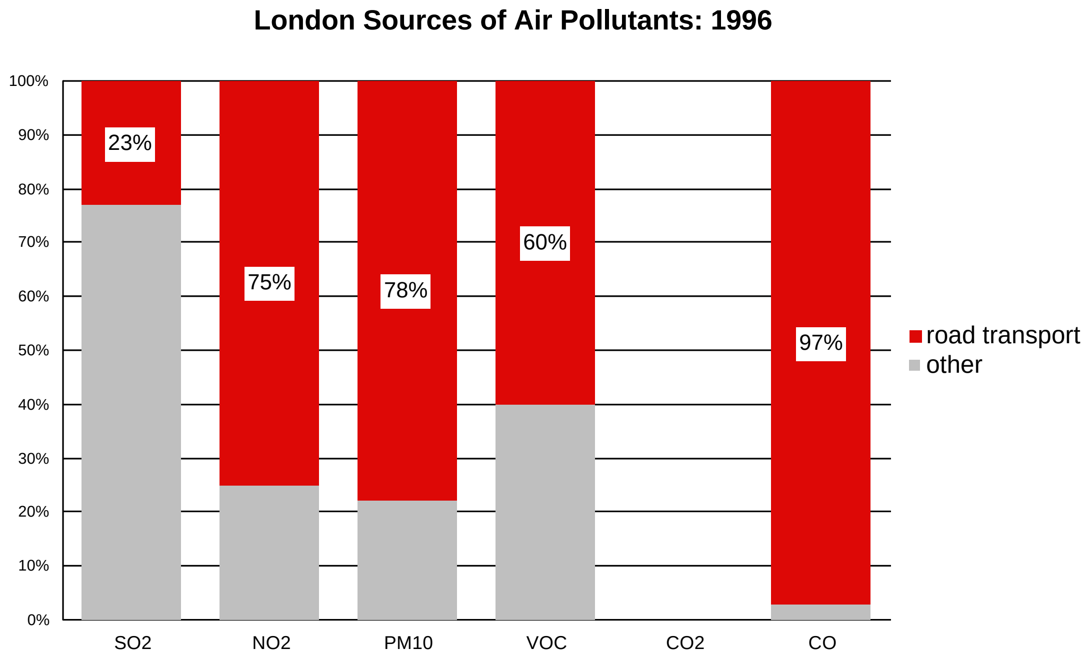
Thus the cumulative low pollution score is "6". That low pollution level rating according to WHO / UNEP in London is only ever exceeded for Carbon Monoxide. A progressive improvement at the central London site monitoring site in Bloomsbury (the site with the longest continuous records) can be seen later.

[27] Atmospheric Research and Information Centre (ARIC) at Manchester Metropolitan University is establishing the Atmosphere, Climate & Environment Information Programme Factsheet 11: Urban Air Pollution in World Megacities

C 2 SOURCES of ATMOSPHERIC POLLUTANTS

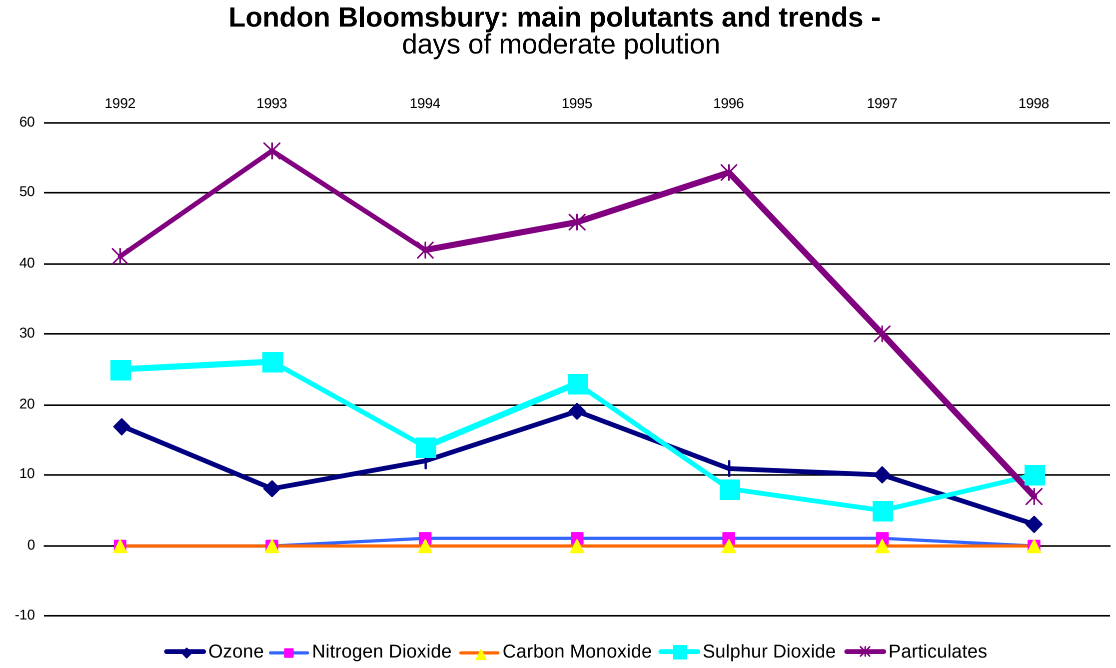


It is not right to assume that traffic is the primary culprit responsible for atmospheric pollution. Road traffic does make significant contributions of certain pollutants but overall it does not constitute the primary sources as can be seen above. However it should be noted that pollutants from traffic are often released in areas of concentrated population and therefore appear to be more significant. In 1996 NETCEN estimated London's emissions sources as below.



Note: comparable CO2 figures not identified.

The NETCEN [28] estimates for 1996 above are in contrast to the pollution improvements recorded in Bloomsbury in central London more recently.



This chart shows days when pollutant levels have exceeded the "low" level year by year. If this improvement is emulated elsewhere in London it would seem that for example for Particulates the days in the year exceeding the "low" level have diminished from 16% to about 2% between 1992 and 1998.

In addition at this central London site the exceedences for Sulphur Dioxide and Ozone also show consistent but less dramatic improvements. It is suspected that these improvements are wide spread across London. It would therefore appear that London traffic derived pollution levels are rapidly reducing to accord with those in the rest of the country.

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[28] DETR: The Environmental Impacts of Road Vehicles in Use Air Quality, Climate Change and Noise Pollution

C 3 INVENTORY of POTENTIAL POLLUTANTS

COMEAP is the Department of Health Committee on the Medical Effects of Atmospheric Pollution. Amongst several subjects it has produced directly relevant advice for Government including:

The Quantification of the Effects of Air Pollution on Health in the United Kingdom 1998 [29]
Non-biological Particles and Health
Asthma and Outdoor Air Pollution
Statement on Banding of Air Quality
etc.

And in addition an Ad-Hoc Group on the Economic Appraisal of the Health Effects of Air Pollutants reported in 1999 [30].

Eight pollutants are named by the DETR [31] in their Road Traffic Reduction Act 1997: Draft Guidance to Local Traffic Authorities as "of particular concern" and the COMEAP advice on each of these can be summarised as follows:

DETR pollutant list	*% from Traffic*	*COMEAP advice*
nitrogen dioxide	48%	discounted as cause of attributable ill-health
particles PM10	25%	potentially damaging to health
ozone	(say) 40%	potentially damaging to health
		but more prevalent in rural areas, rapidly broken down by NO in urban areas
sulphur dioxide	2%	potentially damaging to health
carbon monoxide	75%	discounted as cause of attributable ill-health
lead		not considered (prevention now effective)
benzene		discounted as cause of attributable ill-health
1,3 butadiene		discounted as cause of attributable ill-health
Other Pollutants		
VOCs	28%	discounted as cause of attributable ill-health
Carbon Dioxide	20%	discounted as cause of attributable ill-health
		important greenhouse gas contributing to global warming

This list is used to order the following Inventory of Potential Pollutants.

[29] COMEAP DoH: Committee on the Medical effects of Air Pollution: Quantification of the Effects of Air Pollution on Health in the United Kingdom

[30] DoH: Ad-Hoc Group on the Economic Appraisal of the Health Effects of Air Pollutants Economic Appraisal of the Health Effects of Air Pollution Report

[31] DETR Road Traffic Reduction Act 1997: Draft Guidance to Local Traffic Authorities: Part 4, paras 56 - 59

C 3.1 Nitrogen Oxides (NO - NO_2)

Pollution Chemistry [32]

Nitrogen oxides are formed during high temperature combustion processes from the oxidation of nitrogen in the air or fuel. The principal source of nitrogen oxides - nitric oxide (NO) and nitrogen dioxide (NO2), collectively known as NOx - is road traffic, which is responsible for approximately half the emissions in Europe. NO and NO_2 concentrations are therefore greatest in urban areas where traffic is heaviest. Other important sources are power stations, heating plants and industrial processes.

Nitrogen oxides are released into the atmosphere mainly in the form of NO, which is then readily oxidised to NO_2 by reaction with ozone. Elevated levels of NOx occur in urban environments under stable meteorological conditions, when the airmass is unable to disperse.

Nitrogen dioxide has a variety of environmental and health impacts. It is a respiratory irritant, may exacerbate asthma and possibly increase susceptibility to infections. In the presence of sunlight, it reacts with hydrocarbons to produce photochemical pollutants such as ozone (see below). In addition, nitrogen oxides have a lifetime of approximately 1 day with respect to conversion to nitric acid. This nitric acid is in turn removed from the atmosphere by direct deposition to the ground, or transfer to aqueous droplets (e.g. cloud or rainwater),thereby contributing to acid deposition.

About half the man made (anthropogenic) element of Nitrogen Oxides are generated by road traffic. However at a global level the naturally generated oxides of nitrogen (arising from bacterial action, volcanic eruptions and lightning) far outweigh the amounts generated by man. Thus NOx at low concentrations could reasonably be regarded alongside CO2 as a natural constituent of the atmosphere. Thus although a contribution to acid rain is made by NOx from road traffic, contributions are also made from other sources. Overall these are absorbed in nature by the normal operation of the Nitrogen Cycle.

COMEAP [33] Conclusions: In view of these difficulties and doubts about the relationships between exposure to nitrogen Dioxide and effects on health it was decided not to include nitrogen dioxide in the estimates of the effects of pollutants on health.

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[32] Atmospheric Research and Information Centre (ARIC) at Manchester Metropolitan University is establishing the Atmosphere, Climate & Environment Information Programme Factsheet 4: The Key Air Pollutants

[33] COMEAP DoH: Committee on the Medical effects of Air Pollution: Quantification of the Effects of Air Pollution on Health in the United Kingdom

C 3.2 PARTICULATES PM_{10} $PM_{2.5}$

Pollution Chemistry [34]

Airborne particulate matter varies widely in its physical and chemical composition, source and particle size. PM_{10} particles (the fraction of particulates in air of very small size (<10 μ m)) are of major current concern, as they are small enough to penetrate deep into the lungs and so potentially pose significant health risks. Larger particles meanwhile, are not readily inhaled, and are removed relatively efficiently from the air by sedimentation. Particles are often classed as either primary (those emitted directly into the atmosphere) or secondary (those formed or modified in the atmosphere from condensation and growth).

A major source of fine primary particles are combustion processes, in particular diesel combustion, where transport of hot exhaust vapour into a cooler tailpipe or stack can lead to spontaneous nucleation of "carbon" particles before emission. Secondary particles are typically formed when low volatility products are generated in the atmosphere, for example the oxidation of sulphur dioxide to sulphuric acid. The atmospheric lifetime of particulate matter is strongly related to particle size, but may be as long as 10 days for particles of about 1mm in diameter.

The principal source of airborne PM_{10} matter in European cities is road traffic emissions, particularly from diesel vehicles. As well as creating dirt, odour and visibility problems, PM_{10} particles are associated with health effects including increased risk of heart and lung disease. In addition, they may carry surface-absorbed carcinogenic compounds into the lungs.

Concern about the potential health impacts of PM_{10} has increased very rapidly over recent years. Increasingly, attention has been turning towards monitoring of the smaller particle fraction PM2.5 capable of penetrating deepest into the lungs, or to even smaller size fractions or total particle numbers.

Particulate matter is of real concern as a pollutant, 25% being generated nationally from road traffic. This is plainly visible as smoke and dirty exhaust fumes particularly from diesel vehicles. Particulate emissions from traffic are often released in areas of high population density. Larger particles in smoky exhausts settle out in the atmosphere relatively quickly. When inhaled they are mainly trapped in the nose which provides the body with a very efficient filtration system.

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[34] Atmospheric Research and Information Centre (ARIC) at Manchester Metropolitan University is establishing the Atmosphere, Climate & Environment Information Programme Factsheet 4: The Key Air Pollutants

More and more concern is concentrating on smaller particles in emissions which can be inhaled deeply and can fully penetrate into the airways and lungs. Such particulate matter is a danger to health and particulate matter from traffic can transfer potentially carcinogenic compounds into the lungs.

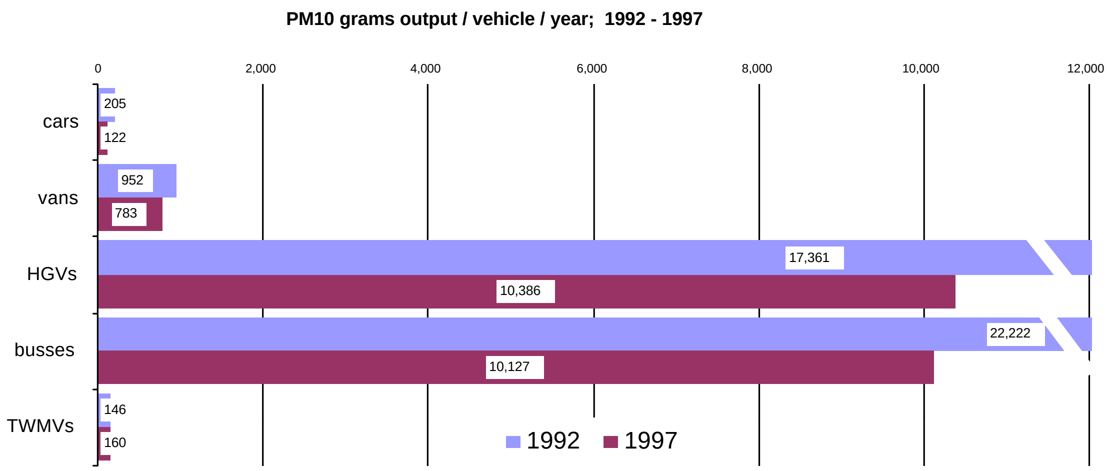
It has been estimated that only about 10% of all vehicles, mainly HGVs, Vans and Buses cause 90% of the particulate pollution. But in the years between 1992 and 1997 these classes of vehicles have seen marked improvements. Nonetheless there is a great deal that can be done with regard to particulate emissions. These actions include:

- the use of improved fuels especially diesel
- particulate traps for diesel vehicles
- active prosecution of polluting offenders: this may be a policing matter and a low priority for them.

Such measures already appear to be having positive effects for example Particulate emission exceedences in Bloomsbury fell 8 fold between 1992 and 1998. This is also reflected in the national [35] figures as follows:

	PM_{10} reductions 1992-97	*PM_{10} contribution 1997*
cars	59%	29%
vans	82%	18%
HGVs	60%	44%
buses	46%	8%
TWMV	109%	1%
overall	58%	

The contribution of PM_{10} by vehicle type can be seen clearly below.



[35] NETCEN / AA

C 3.3 OZONE

Pollution Chemistry [36]

Ground-level ozone (O_3), unlike other primary pollutants mentioned above, is not emitted directly into the atmosphere, but is a secondary pollutant produced by reaction between nitrogen dioxide (NO2), hydrocarbons and sunlight. Ozone can irritate the eyes and air passages causing breathing difficulties and may increase susceptibility to infection. It is a highly reactive chemical, capable of attacking surfaces, fabrics and rubber materials. Ozone is also toxic to some crops, vegetation and trees.

Whereas nitrogen dioxide (NO_2) participates in the formation of ozone, nitrogen oxide (NO) destroys ozone to form oxygen (O_2) and nitrogen dioxide (NO_2). For this reason, ozone levels are not as high in urban areas (where high levels of NO are emitted from vehicles) as in rural areas. As the nitrogen oxides and hydrocarbons are transported out of urban areas, the ozone-destroying NO is oxidised to NO_2,which participates in ozone formation.

Sunlight provides the energy to initiate ozone formation; near-ultra-violet radiation dissociates stable molecules to form reactive species known as free radicals. In the presence of nitrogen oxides these free radicals catalyse the oxidation of hydrocarbons to carbon dioxide and water vapour. Partially oxidised organic species such as aldehydes, ketones and carbon monoxide are intermediate products, with ozone being generated as a by-product.

Since ozone itself is photo dissociated (split up by sunlight) to form free radicals, it promotes the oxidation chemistry, and so catalyses its own formation (i.e. it is an autocatalyst). Consequently, high levels of ozone are generally observed during hot, still sunny, summertime weather in locations where the airmass has previously collected emissions of hydrocarbons and nitrogen oxides (e.g. urban areas with traffic). Because of the time required for chemical processing, ozone formation tends to be downwind of pollution centres. The resulting ozone pollution or "summertime smog" may persist for several days and be transported over long distances.

Ozone is formed in sunny conditions within relatively a static airmass when their are high concentrations of other pollutants. This is a common occurrence in Los Angeles where Ozone smog causes real health problems with common concentrations about 4 times more than that ever recorded in London and the UK. Such episodes in London are rare because weather patterns are not conducive towards them: the last occasion was for three days in 1996. With the continuing reduction of overall pollution levels the condition are likely to become even rarer still.

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[36] Atmospheric Research and Information Centre (ARIC) at Manchester Metropolitan University is establishing the Atmosphere, Climate & Environment Information Programme Factsheet 4: The Key Air Pollutants

In addition as Ozone itself is scavenged and destroyed by Nitric Oxide a more common Pollutant in cities, health risks from Ozone pollution itself are likely to be minimised in London, whereas there is a chance that pollution from London could cause higher risk in surrounding country areas.

C 3.4 SULPHUR DIOXIDE

Pollution Chemistry [37]

Sulphur dioxide is a corrosive acid gas which combines with water vapour in the atmosphere to produce acid rain. Both wet and dry deposition have been implicated in the damage and destruction of vegetation and in the degradation of soils, building materials and watercourses. SO_2 in ambient air is also associated with asthma and chronic bronchitis.

The principal source of this gas is power stations burning fossil fuels which contain sulphur. Major SO_2 problems now only tend to occur in cities in which coal is still widely used for domestic heating, in industry and in power stations. As some power stations are now located away from urban areas, SO_2 emissions may effect air quality in both rural and urban areas. Since the decline in domestic coal burning in cities and in power stations overall, SO_2 emissions have diminished steadily and, in most European countries, they are no longer considered to pose a significant threat to health.

Of particular concern in the past was the combination of SO_2 and black smoke and particulate matter; current EC Directive Limit Values for SO_2 are defined in terms of accompanying black smoke levels, although these are likely to change.

Prior to the 1950's when the clean air acts came into full effect SO_2 along with particulate matter, black smoke (as then measured by passing air through filter paper) was a major contributor to urban air pollution with devastating health consequences.

It has been estimated that the 1952 smog was directly responsible for advancing the death of more than 4,000 Londoners. Because of contemporary legislation about 50 years ago and changes in domestic / industrial fuels used such events no longer occur.

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[37] Atmospheric Research and Information Centre (ARIC) at Manchester Metropolitan University is establishing the Atmosphere, Climate & Environment Information Programme Factsheet 4: The Key Air Pollutants

The national contribution of SO_2 from traffic is now minimal (2%), other sources make up the lion's share of this damaging ingredient of acid rain. Other power generation and industrial sources in the UK do make a significant contribution to acid rain. Normally rather than being widely dispersed as with road traffic, such SO_2 sources are localised and often away from conurbations. Progressively with the introduction of cleaner diesel fuels for transport the traffic generated 2% figure is being reduced even further, but such reduction overall of an already small contribution can have only small further effects on health.

COMEAP Conclusions [38]

There is little doubt that SO_2 both causes and aggravates symptoms particularly in patients with pre-existing asthma. In association with particles it appears to increase mortality both in the short and the longer term, although it is uncertain which component of pollution is mostly responsible. The associations with raised mortality do not seem to be attributable simply to a more rapid demise of people who are dying in any case, since there is some evidence that death rates in chronically polluted areas remain substantially higher than those in cleaner areas. The best current estimates of the acute effects are that each 50 µ g/m3 rise in the 24 hour average concentration raises the death rate by 3% for all causes, 4% for cardiovascular diseases, and 5% for respiratory diseases. It is much more difficult to quantify the chronic effects at present and we take the view that exposure response relationships for chronic effects for the UK are not devisable.

C 3.5 CARBON MONOXIDE

Pollution Chemistry [39]

Carbon monoxide (CO) is a toxic gas which is emitted into the atmosphere as a result of combustion processes, and is also formed by the oxidation of hydrocarbons and other organic compounds. In European urban areas, CO is produced almost entirely (90%) from road traffic emissions. CO at levels found in ambient air may reduce the oxygen-carrying capacity of the blood. It survives in the atmosphere for a period of approximately 1 month but is eventually oxidised to carbon dioxide (CO_2).

At high concentrations Carbon Monoxide is lethal and accounts for some 50 or more deaths per year as a result of faulty or poorly maintained gas heaters. At atmospheric concentrations it disperses and converts rapidly to Carbon Dioxide, the important greenhouse gas. COMEAP were unable to determine a detrimental health effect at atmospheric concentrations.

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[38] COMEAP DoH: Committee on the Medical effects of Air Pollution: Quantification of the Effects of Air Pollution on Health in the United Kingdom

[39] Atmospheric Research and Information Centre (ARIC) at Manchester Metropolitan University is establishing the Atmosphere, Climate & Environment Information Programme Factsheet 4: The Key Air Pollutants

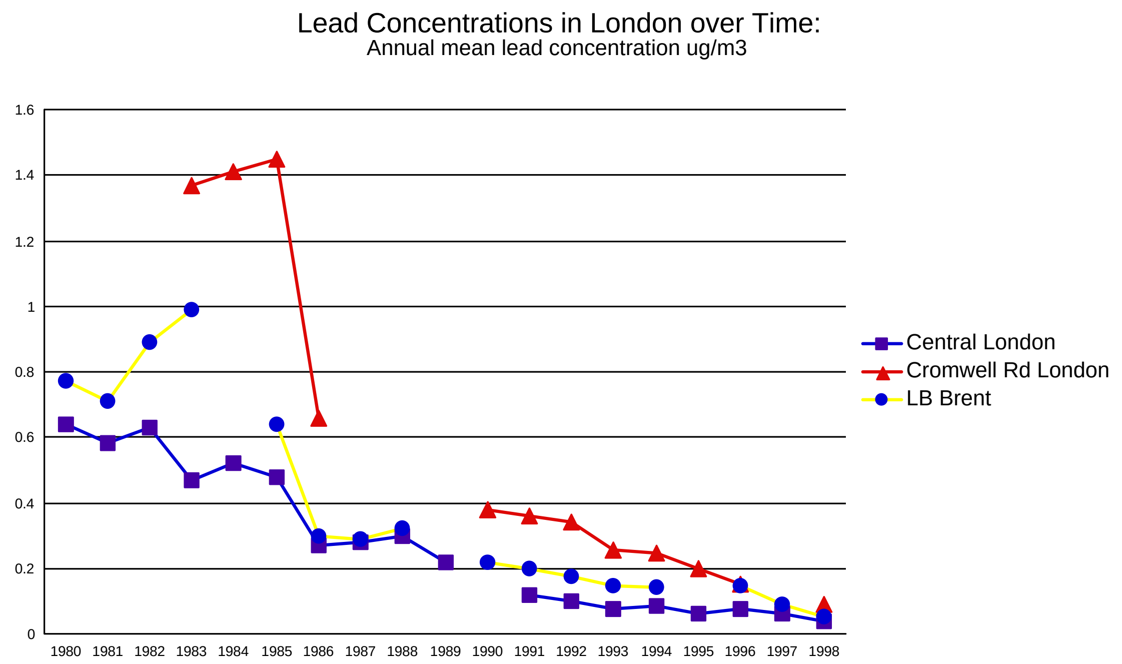
C 3.6 ATMOSPHERIC LEAD

Pollution Chemistry [40]

Particulate metals in air result from activities such as fossil fuel combustion (including vehicles), metal processing industries and waste incineration. There are currently no EC standards for metals other than lead, although several are under development. Lead is a cumulative poison to the Central Nervous System, particularly detrimental to the mental development of children.

Lead is the most widely used non-ferrous metal and has a large number of industrial applications. Its single largest industrial use world-wide is in the manufacture of batteries (60-70% of total consumption of some 4 million tonnes) and it is also used in paints, glazes, alloys, radiation shielding, tank lining and piping.

As tetraethyl lead, it has been used for many years as an additive in petrol; most airborne emissions of lead in Europe therefore originate from petrol-engined motor vehicles. With the increasing use of unleaded petrol, however, emissions and concentrations in air have declined steadily in recent years.



Lead in the environment has posed a major health risk in the past. Its affects particularly in the mental health and probable retardation of children in younger age groups has caused real concern.

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[40] Atmospheric Research and Information Centre (ARIC) at Manchester Metropolitan University is establishing the Atmosphere, Climate & Environment Information Programme Factsheet 4: The Key Air Pollutants

The major source of atmospheric lead was the use of tetraethyl lead as an anti-knock compound in the most commonly used in all petrol up to about 15 years ago. The effect of both legislation and positive tax / pricing incentives has progressively eliminated lead in petrol and no commonly sold petrol will contain lead additives after the year 2000. The progressive effect of the transition to lead free petrol in the London context can be seen clearly in the graph below: data taken from DETR / NETCEN [41] data collection points in London for which the longest continuous time series data is available.

Although lead can now be disregarded as a health threat, the history of its elimination is a good illustration of how a mixture of fiscal incentive and appropriate physical regulation can stimulate rapid change in behaviour.

C 3.7 BENZENE , 1,3 BUTADIENE and VOCS

All these pollutants are potentially dangerous and can be carcinogenic in moderate concentrations. They are also effectively removed from exhaust gases by catalytic converters.

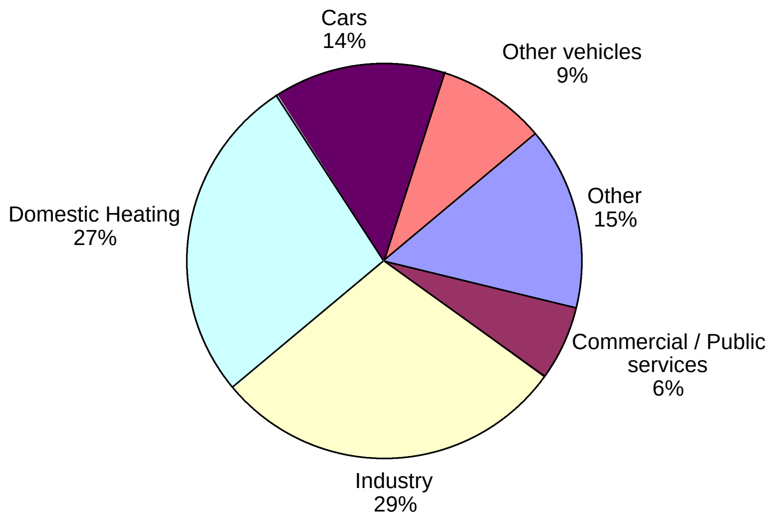
COMEAP [42] discounts their impact on health at the low concentrations that arise in atmospheric pollution.

[41] NETCEN / DETR: The UK National Air Quality Information Archive: Concentrations of Lead in Ambient Air

[42] COMEAP DoH: Committee on the Medical effects of Air Pollution: Quantification of the Effects of Air Pollution on Health in the United Kingdom

C 3.8 CARBON DIOXIDE

Carbon Dioxide is a normal constituent of the atmosphere. Manmade contribution to CO_2 levels are considered to be a / the major contributory cause for global warming and the greenhouse effect. Vehicle emissions make a contribution but are only part of the national contribution as shown below:



It should be noted that fuel replacement strategies which are intended reduce traffic emissions locally are unlikely to reduce CO_2 at a national level: they may even increase CO_2 level by introducing further inefficiencies into the conversion process from energy to fuel, for example with electric powered vehicles. Catalytic conversion of CO and hydrocarbons to CO_2 also makes more immediate the production of the greenhouse gas from traffic sources.

C 4 COMEAP and DEPARTMENT of HEALTH

COMEAP allocates the effects of those pollutants that it considers as potentially damaging to health as follows:

Nationwide	*deaths brought forward*	*respiratory admissions*
particles PM_{10}	8,100	10,500
sulphur dioxide	3,500	3,500
ozone	700	500
total	12,300	14,500
out of urban / total	430,000	530,000
percent	2.86%	2.74%

Attributable to traffic sources of pollutants nationwide

	attributable to Traffic	*deaths brought forward*	*respiratory admissions*
particles PM_{10}	25%	2,025	2,625
sulphur dioxide	2%	70	70
ozone	40%	280	200
total		2,375	2,895
out of urban total		430,000	530,000
	%	0.552%	0.546%

If these estimates are simply pro-rated to the London population we obtain:

Allocated in London	7.7m	*deaths brought forward*	*respiratory admissions*
particles PM_{10}	of 43.0m	363	470
sulphur dioxide	of 43.0m	13	13
ozone (nationally)	of 58.8m	37	26
		412	509

The resulting costs to the NHS in London, (see Annex 1) can be roughly estimated at a rate of £ 2,500 / respiratory admission as being about £ 1.3m. On the obverse, the result of deferring deaths in frail and aging individuals by pollution reduction actually incurs further costs for the NHS. This is estimated by the DoH Ad Hoc group [43] as being between £ 200 (1 month) and £ 2,500 (12 months) so the other balancing adverse costs of reducing pollution could amount to between £ 82,400 and £1.03 m. However any of these figures mentioned must be at level less than the rounding errors in NHS budgets for health provision in London at around 0.05%.

[43] DoH: Ad-Hoc Group on the Economic Appraisal of the Health Effects of Air Pollutants Economic Appraisal of the Health Effects of Air Pollution Report

The DoH Ad-Hoc Group actually goes further in estimating an even further reduced burden on the NHS in assessing the direct costs arising from COMEAP identified pollutants at only £ 0.45m - £ 2.39m. These figures do not account for the diverse origins of the pollutants, nor are they prorated for the London population.

COMEAP

1 summary findings January 1998

KEY FINDINGS
Air pollution damages health;

Over 12000, and maybe as many as 24000, deaths and between 14000 and 24000 hospital admissions brought forward by short-term exposure to air pollution each year, mainly in urban Great Britain (full tables in the attached Annex);

We don't yet know by how much these events are brought forward (e.g. a day, a month or longer) and this will need to be the subject of further research;

Nor do we know the long-term impact of air pollution on health, for which further research is needed, though studies carried out in the United States on the long term impact on health suggest that air pollution may be responsible for shortening life by an average of a year or so;

The risk to healthy individuals is VERY SMALL at all levels of pollution likely to be experienced in the UK.

Those likely to be most affected are the very ill and frail;

THE POLLUTANTS COVERED IN THE REPORT

2 The Committee felt there were sufficient data to allow estimates of effects to be made for ozone, particles and sulphur dioxide on both all causes of deaths and on admissions to hospital for respiratory disorders. They were less sure about the estimates of effects for nitrogen dioxide. For carbon monoxide, there were insufficient data to allow estimates of effects in the UK to be made with acceptable accuracy.

WHAT DO WE KNOW ABOUT AIR POLLUTION AND HEALTH?

3 Studies of populations show that raised levels of air pollutants are one of several factors which can contribute to an increase in the severity of heart and lung disease. Increased hospital admissions and earlier deaths in a population occur as air pollution rises probably as a result of a worsening of the clinical condition of those who are already seriously ill. For any individual patient, it will probably be unclear why a worsening of symptoms has occurred. Air pollution will be one of a number of factors to

be taken into account in the clinical management of people with chronic heart and lung disorders.

WHAT SIZE ARE THE RISKS TO HEALTH?

4 This is difficult to define with great accuracy but, as an example, a rise from a daily average level of particles of 20 microgrammes per cubic metre to 50 microgrammes per cubic metre is thought to be associated with just over 1 extra patient on average being admitted to hospital with respiratory disease in a city with a population of 1 million. To put these data in context, approximately 30000 deaths are precipitated each winter as a result of exposure to lower temperatures.

WHAT CAN THE INDIVIDUAL DO?

5 The risk to healthy individuals is VERY SMALL at all levels of pollution likely to be experienced in the UK. People who suffer from a lung disease such as asthma should be able to manage their condition themselves by increasing their medication if they find that their condition deteriorates on days when pollution is high. Those who suffer from chronic chest diseases such as chronic bronchitis or emphysema may also be more sensitive to changes in air pollution. Some people with heart disease may also be more sensitive. Sufferers from these conditions should always seek medical advice if their symptoms change as it is unclear what proportion of patients or types of heart disease are involved. Patients with heart disease should not in general adjust their medication themselves and there is also a risk of alarming patients unnecessarily.

C 5 ASTHMA and AIRBORNE POLLUTION

It has also been asserted and often assumed that particulate emissions also make a significant contribution to the increase of Asthma [44]. Comparing the incidence of asthma and all emissions [45] show that as the level of emissions has fallen so the incidence of asthma has risen.

COMEAP Conclusions 46

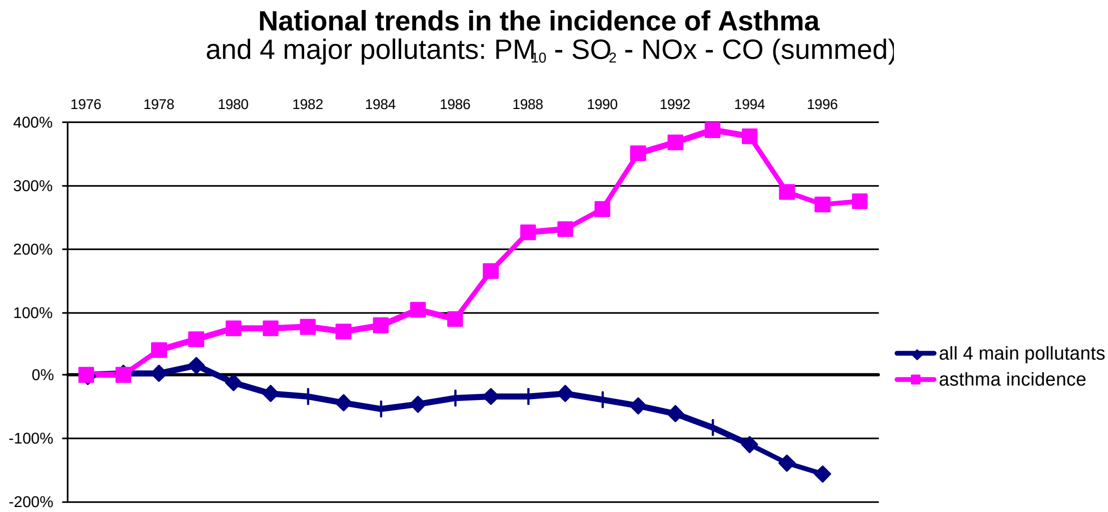
1.16 As regards the initiation of asthma, most of the available evidence does not support a causative role for outdoor air pollution. (This excludes possible effects of biological pollutants such as pollen and fungal spores.)

1.17 As regards worsening of symptoms or provocation of asthmatic attacks, most asthmatic patients should be unaffected by exposure to such levels of non-biological air pollutants as commonly occur in the UK. A small proportion of patients may experience clinically significant effects which may require an increase in medication or attention by a doctor.

1.18 Factors other than air pollution are influential with regard to the initiation and provocation of asthma and are much more important than air pollution in both respects.

Asthma has increased in the UK over the past thirty years but this is unlikely to be the result of changes in air pollution.

The relationship or lack of it is clearly shown in the following graph.



[44] Jack Pease, Air Quality Management: Traffic pollution: the jury still out

C 6 ATMOSPHERIC POLLUTION: PROGRESS and PREDICTIONS

The National Environmental Technical Centre, NETCEN record traffic growth and make continuous forward predictions of likely car ownership and resulting traffic generated. In fact, as we note below London's traffic has not increased in line with growing national car ownership and has remained at a static level over the past 10 years [47]. In addition NETCEN also track pollution levels and model their likely levels into the future.

Since 1992 all new cars have been required to have catalytic converters installed in their exhaust systems. The catalyst converts VOCs (mainly hydrocarbons), other hydrocarbons (Benzene, 1,3 butadiene), carbon monoxide and NOx to carbon dioxide, water and native nitrogen, all normal constituents of the atmosphere. As a result catalytic converters are capable of eliminating as much as 90% of the potentially toxic emissions in vehicle exhaust. However converters are most efficient on long journeys when fully warmed up.

Since 1992 [48] the introduction of replacement vehicles in to the national fleet with catalytic conversion capability has already lead to significant reductions in pollutant output (relative to Q1 1992 at 100%), in spite of a national increase in the number of vehicles, as below:

		for Quarter 1 1999
NOx	DERV	70.3%
	Petrol	60.9%
	all vehicles	65.0%
Carbon Monoxide	DERV	80.2%
	Petrol	60.6%
	all vehicles	61.2%
Non Methane VOCs	DERV	60.9%
	Petrol	54.9%
	all vehicles	55.7%
Benzene	DERV	61.7%
	Petrol	49.9%
	all vehicles	50.7%
PM_{10}	DERV	65.5%
	Petrol	51.1%
	all vehicles	62.0%

[45] ONS Statbase

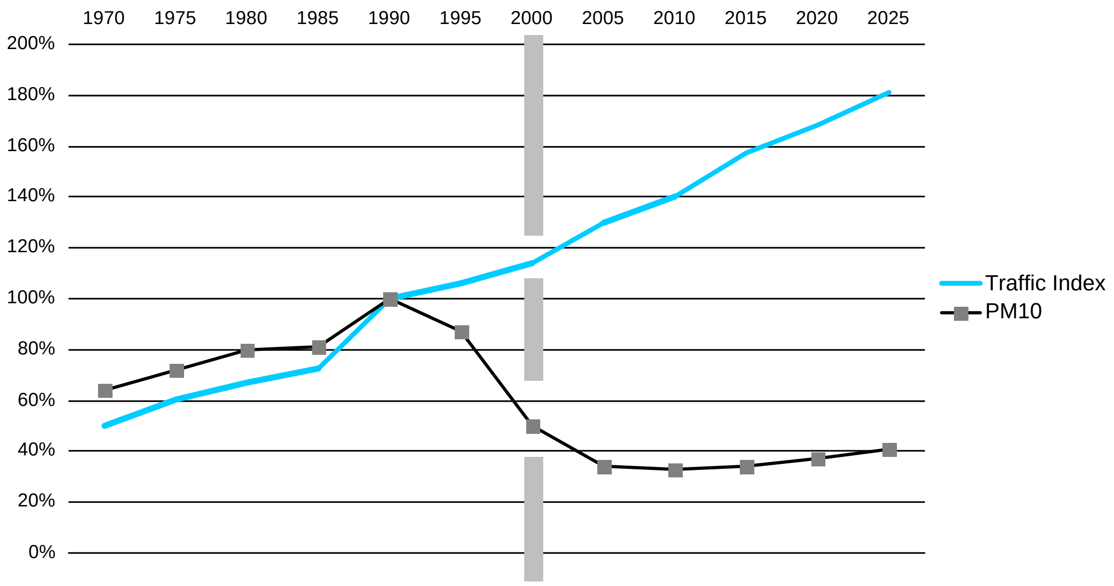
[46] COMEAP: Asthma and Outdoor Air Pollution

[47] Focus on London 1999 Chapter 10

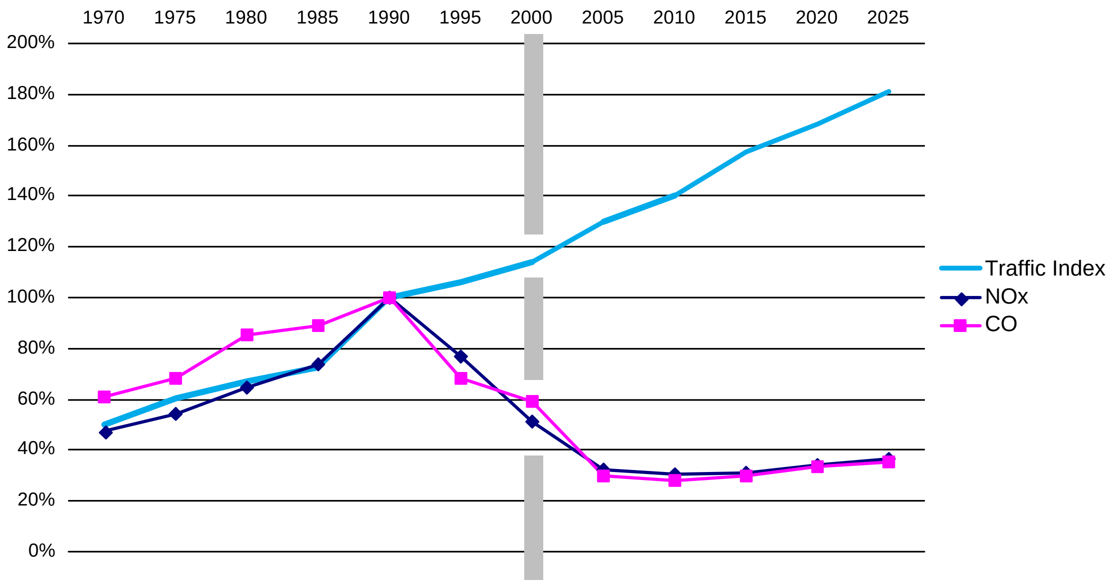
[48] NETCEN / AA

This process is ongoing as the vehicle fleet is progressively replaced by vehicles using the new technology. It is clear from these figures that even though substantial progress has been made with emissions from both diesel (DERV) and petrol engines that diesel pollutant emissions are lagging behind the improvements being made with petrol engines. The following graphs show the national predictions [49]for all main pollutants.

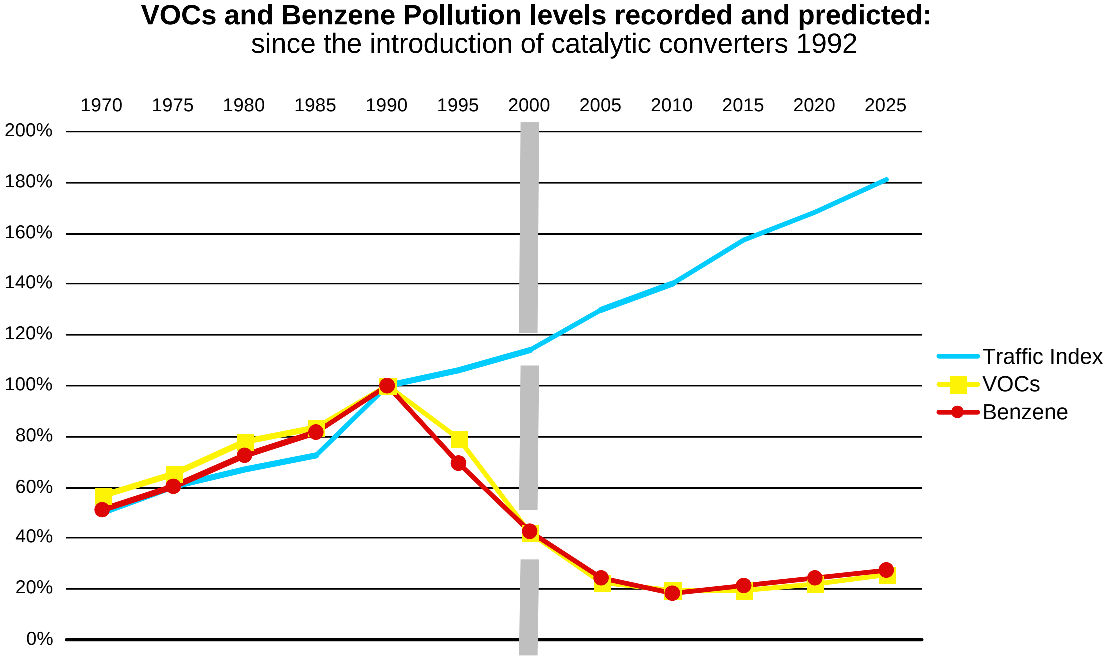
Particulate Pollution levels recorded and predicted:
since the introduction of catalytic converters 1992



NOx and CO Pollution levels recorded and predicted:
since the introduction of catalytic converters 1992



[49] NETCEN / AA



In London traffic growth has substantially stabilised [50] and so the impact of the growth of vehicle number in the fleet is not nearly so great as can be expected to apply nationally. Thus the relatively small upswing in these curves, resulting from the national traffic growth, should less evident in London in the later years. This could well be further enhanced if it is decided to introduce further traffic restraint measures, such as congestion charging, in London.

Estimating levels of pollution in the atmosphere is not the same thing as estimating the exposure suffered by individuals: they are likely to spend most time in locations where pollutants are above average levels. The recording and prediction of individual exposures appears to be a topic of current, incomplete research. Hoteit et al [51] were able to measure personal exposure of a very small sample of individual London commuters and to illustrate variations by mode whilst actually travelling – the car being generally the mode giving most exposure. More experimental and modeling work is required before firm conclusions can be drawn. A complication is caused by the rapidly reducing level of pollutants in the atmosphere, making obsolete observations taken some time ago.

[50] Focus on London 1999 Chapter 10

[51] Hoteit, Gee and Sollars, "Commuters' Exposure to VOCs in London", Centre for Environmental Control and Waste Management, Imperial College London,1996.

C 7 THE INTERNATIONAL LITERATURE on AIR POLLUTION

Although our interest is in London, and London is different from other places in many respects, it is worth noting the state of the art in the international literature. A summary of a selection of articles follows.

McCubbin and Delucchi [52] examine the health costs of motor vehicle related air pollution in the United States. They argue that motor vehicles have significantly larger health costs than previously reported. They find particulates to be the most damaging pollutant, while ozone and other pollutants have smaller effects. The authors adopted a four-stage approach in modeling the relationship between changes in emissions and changes in health costs:

i. Estimate emissions related to motor vehicle use
ii. Estimate changes in exposure of individuals to air pollution
iii. Relate changes in air-pollution exposure to changes in physical health effects.
iv. Relate changes in physical health effects to changes in economic welfare.

Their results showed large damages caused by ambient particulate matter (PM), and also the large contribution of motor vehicles to ambient particulate levels. McCubbin and Delucchi argue that while there is considerable uncertainty in their analysis, it is clear, that over a wide range of assumptions, damage from particulates dominates the total cost of the health effects of motor-vehicle air pollution.

A further perspective on the orders of magnitude involved in adverse affects of traffic on health is provided by Professor D M Newbery [53] . He reviews the evidence on social and environmental costs that result from road-use. The report does not set out to analyse the health impact of transport exclusively but some of the author's results prove relevant. He argues that there is a general consensus that the larger part of the costs of transport pollutants are those associated with impacts on human health - increased mortality, morbidity, and chronic conditions such as asthma.

[52] McCubbin DR and Delucchi MA (1999) 'The health costs of motor vehicle-related air pollution', Journal of Transport Economics and Policy.
[53] Newbery D (1998) Fair payment from road-users: a review of the evidence on social and environmental costs. Basingstoke: Automobile Association.

Drawing upon results reported in Delucchi, Newbery is able to show that health costs (mortality and morbidity) of particulates alone account for 45-50 percent of the total identified external costs of vehicle use, while the health costs of all air pollutants account for 60-83 percent of the total. There is however, considerable uncertainty about the true size of these costs. For instance, for Newbery reports a low pollution health cost by vehicle for the US of 0.36 pence per km and a high figure of 5.36 pence / km, both in 1996 prices. Much of the variation can be explained by the lack of appropriate information allowing for the accurate allocation of costs. Newbery argues for estimating the health effects of pollution by estimating the number of quality life years lost through pre-mature mortality and morbidity. These costs could then be compared with what it costs the NHS to achieve an extra year of quality health. In this way money raise in 'green' taxes could be allocated to the NHS to compensate for the quality life years lost through pollution by an equal amount reflecting the quality life years gained from improved health services

The eighteenth report of the Royal Commission on Environmental Pollution, the 'Houghton Report' [54], set out to propose ways in which the longer-term development of transport could be made environmentally sustainable. This, the report stated, meant allowing the access required for continued economic growth, for livelihood and leisure, while eliminating many of the damaging aspects of transport. The Commission investigated the effects of air quality on health. They reported results from a variety of studies that indicated a high degree of uncertainty over the magnitude of health risks arising from air pollutants. The Commission did, however, welcome any reduction in levels of particulates and recommended that a precautionary approach be taken which would seek to reduce emissions of particulates as far as is practicable. The commission also drew attention to accidents caused by transport. They endorsed the existing Government's objective of reducing injuries from road accidents to two-thirds of the 1981-85 level by 2000. The commission believed that a sustainable transport policy must involve a major increase in the proportion of trips made by walking or bicycle. They stressed that in bringing that trend about appropriate accompanying measures to ensure increased safety would have to be taken.

[54] Royal Commission on Environmental Pollution (1994) Eighteenth Report: Transport and the Environment. London: HMSO.

A report by the Automobile Association [55] contains vehicle emission indices produced by the National Environmental Technology Centre (NETCEN). It shows that while vehicle exhaust fumes contain a number of toxic emissions that raise concerns about health, despite traffic growth, the level of toxic emissions are falling. The report predicts that by 2015 emissions will be half the 1997 level. The reasons given for falling levels of toxic emissions include:

- The implementation of international agreements aimed at reducing vehicle emissions improved engine technology and fuel quality
- The requirement from January 1993 for all new built petrol engine cars to have a catalytic converter
- Reductions in the sulphur content of diesel fuel and the development of a new generation of diesel engines which has substantially reduced emissions of small particles.

Small and Kazimi [56] set out to measure the costs of regional (tropospheric) air pollution from motor vehicles in the United States. They note that transport accounts for substantial fractions of direct emissions of three primary pollutants: volatile organic compounds (VOC), carbon monoxide (CO), and nitrogen oxides (NOx). More recently, concern had broadened to include the emission of Carbon Dioxide (CO2) due to the potential effects on global warming.

The authors sought to infer the costs of air emissions using by direct estimation of damages. This method traces the links between air emissions and adverse consequences and attempts to place economic values on those consequences. The method measures several links in the causal change of pollution separately, for instance, by understanding the atmospheric conditions, topographical features, and the presence of other man-made chemicals in the air – all of which determine the ambient concentration of emitted pollutants.

Small and Kazimi focus on effects on human health. They estimate three main categories of costs for the Los Angeles region: mortality from particulates, morbidity from particulates, and morbidity from Ozone. They review the evidence for the existence of associations between ill health and particulates and ozone.

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[55] Automobile Association (1997) Tracking emissions from UK vehicle exhausts: the AA toxic tailpipe indices. Basingstoke: Automobile Association.

[56] Small, K A and Kazimi C (1995) ‘On the costs of air pollution from motor vehicles’, Journal of Transport Economics and Policy, 29 (1), 7-32.

They conclude that sulphate aerosols and other components of PM10 cause increased mortality. They quote coefficients from a 1987 study by Özkaynak and Thurston which measures the increased annual metropolitan-area deaths per 100,000 of the population for a unit increase in particulate concentration in micrograms per cubic metre (µg / m3). The coefficients (standard errors in parenthesis) were 6.6 (1.5) for SO_2, 2.2 (0.8) for FP, and the authors imputed an additional coefficient for PM_{10} of 1.298.

Small and Kazami report a variety of results that show that poorly controlled vehicles do have significant pollution costs. Diesel cars and trucks have the highest costs due to their direct and indirect contributions to ambient concentrations of particles. For most typical vehicles of the 1990s, however, the authors show that internalizing air pollution costs would not alter car use very much. Their best estimate for the air pollution cost of the average car on the road in Los Angeles in 1992 is $0.03 per vehicle mile, falling to half that amount by the year 2000.

The authors argue that these findings amount to a strong prima facie case for policies that reduce the emissions from individual vehicles, but do not provide much support for policies to reduce motor vehicle use overall. 'It is not sufficient', the authors conclude, (p 29)

> *'…to point out that motor vehicles are polluting; unless researchers can find quantitative links to economic loss that are much stronger than those we have found, motor vehicle pollution seems best addressed by measures that reduce the emissions associated with a given amount of motor vehicle use.'*

Michaelis [57]examines the role that alternative fuels can play in reducing local pollution and greenhouse gas emissions from road transport. The author considers the cost, availability and policy effectiveness of reducing emissions with a range of alternative fuel and electric vehicle options. Michaelis presents evidence which shows that alternative fuels and electric vehicles have the potential to reduce urban air pollution when used in cars with dedicated engines with optimised exhaust control systems. Greatest emission reductions are obtained with Hydrogen, followed by CNG and LPG. Electric vehicles have no emissions at the point of use, but the emissions of NOx and SO_2 as a result of the power generation required can exceed those from gasoline vehicle use. The author points out that typically the alternative fuels that give the greatest emissions reductions are also the most expensive.

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[57] Michaelis L (1995) 'The abatement of air pollution from motor vehicles: the role of alternative fuels', Journal of Transport Economics and Policy, 29 (1), 71-92.

Glazer et al [58] report reasons for the failure of the Californian smog check programme to reduce emissions to the level predicted when the policy was first introduced. Upon introduction in 1984 the US Environmental Protection Agency had estimated that the programme could reduce emissions of Hydrocarbon (HC) and Carbon monoxide (CO) by 25 percent. The actual figures in 1987 showed a reduction in HC emissions of only 12.3 percent and a reduction in CO emissions of only 9.8 per cent. The authors identified several reasons for the failure of the programme:

i. The programme only encouraged cars to be clean on one day every two years - the inspection day.
ii. Motorists were not deterred from tampering with the connected smog devices.
iii. Although most emissions were found to come from a few vehicles with high emissions, the programme required the inspection of all cars.
iv. Cars were not being repaired properly - about half the cars repaired by garages following an inspection were found to have increased emissions.

Hall [59] starts from the premise that while cleaner fuels and engines can reduce air pollution, they have not reduced emissions enough to meet environmental objectives, nor have they done anything to reduce congestion. The author focuses on assessing the role of transport control measures (TCMs) at achieving lower emission and reducing congestion. TCMs can be divided into three basic groupings:

i. Provide alternatives to single occupancy vehicles (SOVs) - i.e. improved public transport, reserved high-occupancy vehicle (HOV) lanes, bus lanes, ride sharing facilitation, bicycle - pedestrian paths, HOV and public transport parking.
ii. Discourage light duty vehicle (LDV) use - i.e. trip reduction ordinances, employer-based transport demand management, road or area restriction, reduce event related SOVs.
iii. Reduce travel demand - i.e. employer-based transport demand management, bicycle facilities, flexible work scheduling.

[58] Glazer A, Klein DB, and Lave C (1995) 'Clean on paper, dirty on the road: troubles with California's smog check', Journal of Transport Economics and Policy, 29 (1), 85-92.
[59] Hall JV (1995) 'The role of transport control measures in jointly reducing congestion and air pollution', Journal of Transport Economics and Policy, 29 (1), 93-103.

The author argues that the ability of TCMs to reduce congestion and pollution depends on whether travel demand and SOV use are reduced without changing fleet composition and LDV operating conditions in ways that increase average emissions. Hall finds that TCMs that improve traffic flow can lead to increased emissions, but also stresses that average emissions depend on a complex array of variables. For this reason there are several uncertainties surrounding the potential effects of TCM measures.

Eyre et al [60] develop an approach which applies damage cost results derived in the electricity generation sector to road transport emissions at the local and regional scale. The authors point out that the calculation of monetary damages arising from air pollution at the local and regional levels has generally been considered impracticable to undertake. The monopolistic character of the electricity generation sector, however, has given impetus for the calculation of monetary values of pollution to inform appropriate regulatory frameworks. Eyre et al point out that the two sectors are very different and that care needs to be taken in the transferal of results. In particular they acknowledge that the following two characteristics need to be recognised:

i. Electricity sector emissions are mainly from high stacks, whereas road transport emissions are close to ground level.
ii. Electricity emissions are concentrated at a few locations, largely in rural areas, whereas exhaust emissions occur in a range of environments from the open countryside to the centres of major conurbations.

The authors derived the human health damages of road transport emissions from dose response functions, which measure the impact of pollutant concentrations on human mortality and morbidity. The results are shown in the table below. The largest damages are those directly linked to acute mortality from respirable particulates (PM_{10}). The largest impacts of sulphur dioxide and NOX arise from aerosols. For NOx and VOC the impacts of ozone are also significant. The health-direct effects of pollutants are much higher in urban than rural areas.

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[60] Eyre NJ, Ozdemiroglu E, Pearce DW, and Steele P (1997) 'Fuel and location effects on the damage costs of transport emissions', Journal of Transport Economics and Policy, 31 (1), 5-24.

Health Damage attributable to transport emissions (in pence/gram emitted).

Impacts	*Emission*	SO_2	*NOx*	PM_{10}	C_6H_6	*VOC*
Health direct	Rural	0.13	0.04	0.88	2.1	nq
	Urban	2.47	0.18	5.63	13.4	nq
Health aerosols	All	0.18	0.31	ne	ne	ne
Health ozone	All	ne	0.14	ne	ne	0.19

ne = no effect

nq = not quantified

Source: Eyre et al (1997)

The authors went on to distinguish the health damage costs of transport emissions arising from different types of fuel for urban and rural areas. These results are presented in the following table.

Health damage costs of transport emissions (pence/km)

Emission	*Damage costs (in p/km)*					
	Rural Emissions			*Urban Emissions*		
	Petrol	*Gas*	*Diesel*	*Petrol*	*Gas*	*Diesel*
Particulates	0.003	0.000	0.151	0.003	0.000	1.692
Sulphur dioxide	0.024	0.001	0.014	0.173	0.001	0.182
Sulphate aerosol	0.033	0.001	0.020	0.038	0.001	0.027
Oxides of nitrogen	0.013	0.007	0.029	0.076	0.054	0.113
Nitrate aerosol	0.101	0.057	0.228	0.163	0.103	0.219
Ozone from NOx	0.045	0.026	0.102	0.073	0.046	0.098
Benzene	0.012	0.000	0.004	0.126	0.001	0.052
Ozone from VOC	0.110	0.017	0.017	0.145	0.018	0.041
Sub-totals	0.341	0.109	0.565	0.797	0.224	2.424

For both urban and rural areas the health costs associated with emissions from the natural gas vehicle fuel cycle are significantly lower than for the liquid fuels. Diesel fuel has the highest health costs and particularly through particulates in urban areas.

Eyre et al argue that the damages to health and the environment are significant compared to the cost of fuel, and that these costs are significantly higher in urban areas, primarily because of the higher pollution dose to people. For the UK, the authors claim that to the extent that external costs are not reflected in fuel prices, transport fuel markets are inefficient and the environment suffers.

Conclusions on the international literature

There is no consistent opinion in the literature about the magnitude of adverse health effects arising from road transport emissions. Some studies have identified substantial health damage others have found relatively minor effects.

Where adverse health effects have been identified the uncertainty around the 'damage' or 'cost' estimates of emissions is typically large. The high degree of uncertainty is due to an absence of reliable data and the variability of circumstances.

Where authors have reported 'best' estimates of the external costs associated with road transport emissions these are often very small. Internalising, or making the polluter pay these costs unlikely to have a noticeable effect on road use or fuel consumption.

Emission levels vary quite substantially by vehicle type, fuel type, location of use and age. There is some evidence that targeting specific vehicle types and ages could significantly reduce emissions. The most damaging pollutant from a health point of view is probably particulates – often generated by old design or badly maintained diesel engines – produced in urban areas.

C 8 TRANSPORT POLICIES AND MEETING NAQS OBJECTIVES

There are various measures that might be taken to influence traffic levels with the aim amongst other things, of securing health benefits. These are either fiscal measures – changing rates of taxation – or direct controls. Their efficacy will depend upon how responsive traffic is to these measures. This is often estimated in terms of elasticities and a selection of studies is summarised next.

Goodwin [61] updated previous work on petrol price elasticities in his review of academic and non-academic studies undertaken in the 1980s and 1990s, emphasising the difference between short and long run effects. His paper showed that more recent work had generally revised the magnitude of elasticity estimates upwards. The unweighted mean value of 120 elasticities of petrol consumption with respect to fuel prices considered in the review is -0.48, compared with similar values from previous reviews of -0.1 to -0.4.

Goodwin highlights differences between recent studies by categorising estimates of the elasticity of petrol consumption with respect to fuel price into cross-section or time series, and sub dividing this distinction into short term, long term, or ambiguous. The 'short term' period generally refers to less than one year and the ambiguous category refers to estimates obtained from models with no explicit consideration of the time dimension. Goodwin's summary of results is reproduced in the Table below.

Summary of Evidence from Studies of Elasticity of Petrol Consumption with Respect to price.

	Explicit		*Ambiguous*
	Short term	*Long term*	
Time-series	-0.27	-0.71	-0.53
	(0.18, 51)	(0.41, 45)	(0.47, 8)
Cross-section	-0.28	-0.84	-0.18
	(0.13, 6)	(0.18, 8)	(0.10, 5)

Note: Figures in brackets are standard deviations and the number of quoted elasticities in the average.
Source: Goodwin (1992)

[61] Goodwin, P.B. (1992) 'A review of new demand elasticities with special reference to short and long run effects of price changes' Journal of Transport Economics and Policy, vol. XXVI (2), 155-163.

The results show that a difference in magnitude exists between the short and long term effects of fuel price increases on petrol consumption. Long term elasticities tend to be between 50% and three times higher than the short term.

The review also considered the effects of petrol prices on traffic levels. An earlier paper by Dix and Goodwin (1992) hypothesised that that the short run elasticities of traffic levels and of petrol consumption with respect to fuel price would be identical, but that they would diverge over time as the long run petrol consumption elasticity grew faster than the traffic elasticity. The reasoning here was that changes in trip rates, car ownership, destination choice, and location decisions would take some time to occur, and that changes in vehicle size and efficiency would have a strong effect on consumption while preserving mobility.

Goodwin's evidence of elasticity effects on traffic levels from fuel prices are shown in the table.

Summary of Evidence from Studies of Elasticity of Traffic with Respect to price.

	Explicit		*Ambiguous*
	Short term	*Long term*	
Time-series	-0.16	-0.33	-0.46
	(0.08, 4)	(0.11, 4)	(0.40, 5)
Cross-section	-	-0.29	-0.5
		(0.06, 2)	(N / A., 1)

Source: Goodwin (1992)

The table reveals important flaws in the Dix and Goodwin hypothesis. While it is that case that long term elasticities are much larger than short term, both short and long term effects of petrol prices on traffic levels are much less than their effects on petrol consumption. Goodwin notes that this is indicative of very rapid behavioural responses that affect petrol consumption more than traffic. He suggests that they may be to do with changes in driving style or speed, or by modifying the least energy efficient journeys.

Goodwin summarises his results by distinguishing the implications of a real 10% increase in fuel prices:

- Short run - a reduction in traffic of approximately 1.5% and a decrease in fuel consumption of about 3%
- Long run - a reduction in traffic of 3% to 5% (split between a reduction in car ownership and a decrease in car use, with neither being more than 3% on its own), and a decrease in petrol consumption of 7% or more.

Thus it would seem that petrol price manipulation would be a more effective tool where the objective is to decrease fuel consumption than it is to reduce road congestion.

With respect to time effect in the magnitude of elasticities Goodwin draws three important implications. First, that behavioural responses to cost changes take place over time and that this implies that time-independent estimates are subject to error. Second, that the range of responses considered credible has to be extended to include changes in car ownership, vehicle type, location decisions and the use of public transport. Third, that policy options are wider than perceived by earlier studies and that pricing has a powerful cumulative effect on the pattern of travel demand.

Oum et al [62] summarised studies of own-price elasticities of demand for transport. Their focus was on methodological approaches and conceptual issues surrounding the definition of elasticities as well as on empirical results. Their paper considered elasticity estimates for private and public travel and freight transport. We focus here only on their discussion of demand elasticities for private automobile use.

Oum et al reported elasticity estimates of automobile usage for the US, Australia and the UK, and for three time horizons defined by the original authors' judgement: short run, long run, and unspecified. All estimates they used were from single mode studies that use household survey data. The authors claimed that the estimates show, for the three countries considered, that the demand for automobile usage is fairly inelastic ranging from -0.09 to -0.52.

[62] Oum, T.H., Waters II, W.G. and Yoong, J. (1992) 'Concepts of price elasticities of transport demand and recent empirical estimates: an interpretative survey' Journal of Transport Economics and Policy, vol. XXVI (2), 139-154.

Although the indication was that long run elasticity estimates are generally higher, Oum et al found that the difference was not significant and they believed that this may be because few studies have developed genuinely long run models (i.e. which incorporate changes in vehicle ownership and location choice). Certainly, the variance in the degree of magnitude of the estimates within each time horizon was sufficiently large to preclude any conclusion on the influence of time specifications. On this basis Oum et al stated that monetary disincentives may not be very effective in restricting automobile usage.

In conclusion to their survey Oum et al highlighted the difficulties created by differing common practices in many existing estimates of transport elasticities. These include the use of ad hoc demand specifications, arbitrary definitions of time horizons, the absence of inter-modal price effects in models, and differing levels of market disaggregation. For these reasons, the authors concluded that there is no easy way of obtaining reliable elasticity estimates for a specific transport market without a detailed study of that market.

Sterner et al [63] examined the price sensitivity of transport gasoline demand. They reported results from earlier surveys (Dahl and Sterner, 1991a, 199b) which stratified a wide variety of previous results by the type of model and data used, and calculated average elasticities for each category. Results from dynamic models for OECD countries over the period 1960-85 show great degrees of difference in the short and long term magnitude of price and income elasticities. The short run price elasticity of gasoline demand varied between -0.10 to -0.24 depending on the model estimated. The equivalent long run figure was between -0.54 and -0.96. Averaging these estimates gave a short run value of -0.23 and a long run figure of almost three and a half times as large, -0.77. The average national income short run elasticity was given as 0.39 and the long run as 1.17. Sterner et al took these figures as evidence that only a very small part of adaptation is of the short run ‘less driving’ type. Also, the fact that the absolute value of the income elasticity was higher than for price indicates that gasoline prices must rise faster than the rate of income growth if gasoline consumption is to be stabilised at present levels.

[63] Sterner, T., Dahl, C. and Franzén, M. (1992) ‘Gasoline tax policy: carbon emissions and the global environment’, Journal of Transport Economics and Policy, vol. XXVI (2), 109-119.

Sterner et al presented the short and long run price and income elasticity estimates generated from lagged endogenous models for 20 OECD countries. These figures are shown in the table below.

Price and Income elasticity estimates of gasoline demand estimates, OECD countries, 1960 - 1985.

	Price Elasticities		*Income elasticities*	
	SR	LR	SR	LR
Canada -	0.25	-1.07	0.12	0.53
US -	0.18	-1.00	0.18	1.00
Austria	-0.25	-0.59	0.51	1.19
Belgium	-0.36	-0.71	0.63	1.25
Denmark	-0.37	-0.61	0.34	0.71
Finland	-0.34	-1.10	0.39	1.26
France	-0.36	-0.70	0.64	1.23
Germany	-0.05	-0.56	0.04	0.48
Greece	-0.23	-1.12	0.41	2.03
Ireland	-0.21	-1.62	0.12	0.93
Italy	-0.37	-1.16	0.40	1.25
Netherlands	-0.57	-2.29	0.14	0.57
Norway	-0.43	-0.90	0.63	1.32
Portugal	-0.13	-0.67	0.37	1.93
Spain	-0.14	-0.30	0.96	2.08
Sweden	-0.30	-0.37	0.51	0.99
Switzerland	0.05	0.09	0.85	1.54
UK	-0.11	-0.45	0.36	1.47
Australia	-0.05	-0.18	0.18	0.71
Japan	-0.15	-0.76	0.15	0.77
Turkey	-0.31	-0.61	0.65	1.29
Mean	-0.24	-0.79	0.41	1.17

Source: Sterner et al (1992)

The long run mean price elasticities for the OECD countries are approximately 3.3 times as large as the short run effects. The long run income effect is about 2.8 times as large as the short run. Short run price elasticities range from 0.05 in Switzerland to -0.57 in the Netherlands, and the long run figures from 0.09 in Switzerland to -2.29 in the Netherlands. For the UK, the short and run long figures are of much lower magnitude than the mean OECD figures (-0.11 compared to -0.24, and -0.45 compared to-0.9). The difference in order of magnitude for the UK between the short and long run is, however, much greater, with an elasticity of about 4.1 times as large in the long term.

Sterner et al considered the effects on the OECD countries of hypothetical tax changes. Given their assumed population and income growth rates they found that with no tax change, the consumption of gasoline and carbon emissions would increase by 47% between 1987 and 2000. If the gasoline tax rate of all OECD countries was raised to the maximum current level (Italian level), gasoline consumption would be reduced by 32% over the same period. But North America would account for this reduction with a slower pace increase in European consumption.

Eltony [64] estimated household gasoline demand in Canada using pooled time-series and cross sectional provincial data. His model recognised three main behavioural responses of households to changes in petrol prices: drive fewer miles, purchase fewer cars, and buy more efficient vehicles. Eltony estimated five separate equations that attempted to explain: gasoline demand per car, the stock of cars per household, new car sales per household, new car fuel efficiency, and the sales ratio of new cars.

Eltony used pooled time-series and cross-section data on the Canadian provinces from 1969-1988. Results for each of the five separate estimations were as follows:

- Estimation of gasoline per car - the short run gasoline price elasticities per car, holding fuel economy constant, was estimated at -0.21. The results also gave a short run income elasticity of 0.15 and unemployment rate elasticity of -0.05.
- Estimation of stock of cars per household - the gasoline price elasticity of the stock of cars per household was found to be small, approximately -0.12, but was in fact an estimate of the short run elasticity.
- Estimation of new car sales - the coefficient of gasoline cost per mile indicated an elasticity of -0.27. The elasticities for income per household and the unemployment rate were found to be 0.34 and -0.30 respectively.
- Estimation of fuel efficiency of new cars - this estimation employed a lagged structure on gasoline price. R2 and minimum standard error results indicated that the optimum lag length is 4 years.

[64] Eltony, M.N. (1993) 'Transport gasoline demand in Canada' Journal of Transport Economics and Policy, vol. XXVII (2), 193 - 208.

Eltony took this finding as evidence that design changes are made 1 to 4 years prior to the year of marketing the final product. Over the four year design period he founds that the gasoline price elasticity of new car fuel efficiency was about 0.8. Estimation of sales ratios of new cars - this estimation was concerned with new car choice between sub-compact, compact, mid-size and large cars. His results showed that the larger the difference between the price of large and small new cars, the smaller was the ratio of large to small sales. As gasoline costs increased, the sale of smaller cars became more frequent relative to sales of larger ones. Also, as household disposable income rose the ratio of sales of the smallest cars to all other categories fell, but a rise in the unemployment rate induced households to reduce car size.

From these estimates Eltony went on to determine dynamic price elasticities of gasoline demand for Canada by simulating the model over the period 1989 - 2000. He assumed a base case in which real household income, the unemployment rate, the real price of new cars, the interest rate, and the real price of gasoline per gallon in Canada and the US were equal to 1988 values and remained constant for the rest of the time horizon. In an alternative solution to the model the real prices of gasoline in Canada and the US were assumed to increase by 10%. The two model solutions were obtained and the percentage change in gasoline consumption computed.

His results for short term (one year) and long term (two to ten years) are given in the table below.

Dynamic Price elasticities of gasoline demand in Canada.

year	
1	-0.3120
2	-0.4673
3	-0.5370
4	-0.5981
5	-0.6984
6	-0.8132
7	-0.8935
8	-0.9478
9	-0.9839
10	-1.0073
11	-1.0192
12	-1.0239

Source: Eltony (1993)

The table demonstrates a number of important points about short run and long run effects of increasing the price of fuel. The short run dynamic own price elasticity of gasoline ranges between -0.311 and -0.31 across the Canadian provinces. Almost 75% of household response to price changes in the first year can be attributes to driving fewer miles. A further 10% results from an alteration in the composition of the fleet to more fuel efficient vehicles and the remaining 15% can be attributed to changes in the size of the fleet. Eltony also found intermediate term (5 year) price elasticities ranged from -0.689 to -0.709 and the long term elasticities from -0.975 to -1.059, and table A9 also shows a rapid response to price increases within the first four years. Eltony interpreted these results as pointing to the importance of improving fuel efficiency as an effective means of reducing household gas consumption.

Rouwendal [65], in an empirical analysis of Dutch data, attempted to obtain direct measures of the short and long term behavioural responses discussed by Goodwin (1992). The author obtained information about fuel use per kilometre driven from the Dutch Private Car Panel, a rotating panel in which car drivers participate for three months. Rouwendal sought to investigate the relationships between fuel use and other recorded information about cars and their drivers. With respect to cars, he was able to observe weight, cylinder volume, year of construction, and type of fuel. Known driver characteristics included sex, classifications of age and income, total number of kilometres driven each year by the main car user, information about business, whether the driver receives compensation for the cost of the car, and for employed people, the distance between residential and work location. Shell provided monthly information about fuel prices in Holland.

The author presented OLS estimates for specifications that were linear in parameters with the logarithm of the number of kilometres driven per litre of fuel as the dependant variable. His results showed that heavier cars are less fuel efficient than others, while diesel cars are more fuel efficient. Surprisingly, the logarithm of the income of the main driver was insignificant and appeared to have little effect, but the type of employment did. People without jobs, managers and the self employed all had less fuel efficient driving styles. Gender effects were not found nor were compensation for motoring costs, but age was important with older drivers generally being less fuel efficient.

[65] Rouwendal, J. (1996) 'An economic analysis of fuel use per kilometre by private cars', Journal of Transport Economics and Policy, vol. XXX (1), 3-14.

As regards the price of gasoline, Rouwendal estimated an elasticity of 0.15, such that a 10% increase in fuel price would induce drivers to increase the average distance per litre of fuel by 1.5%. No significant effects from prices of diesel or LPG were detected, but this lack of evidence may be related to the much smaller number of drivers using this type of fuel.

Rouwendal regarded his central result as being the significant effect of gasoline prices on fuel use which confirmed Goodwin's assertion of the existence of short run effects.

Johansson and Schipper [66] examined aspects of car fuel in relation to decreasing overall travel and increasing fuel efficiency for 12 OECD countries over the period 1973 to 1992: US, UK, Japan, Australia, Germany, France, Italy, The Netherlands, Sweden, Denmark, Norway and Finland. The fuel use data they acquired was disaggregated in such a way that it allowed them to conduct separate estimations for vehicle stock, mean fuel intensity, and mean annual driving distance. The fuel use data also differentiated petrol, diesel, LPG, and CNG (compressed natural gas). The International Energy Agency and the US Department of Energy provided fuel price data. Johansson and Schipper chose to use the average price of petrol and diesel fuel, weighted by the actual quantities of petrol and diesel fuel used by cars and personal light trucks. The nature of other explanatory variables used varied by nation.

Johansson and Schipper used a variety of different estimation techniques and models. The table below presents a summary of their results for the three separate components and for long run car fuel and car travel demand.

[66] Johansson, O and Schipper, L (1997) 'Measuring the long run fuel demand of cars: separate estimations of vehicle stock, mean fuel intensity, and mean annual driving distance', Journal of Transport Economics and Policy, vol. XXX1 (3), 277-292.

Approximate range of the estimated long run parameters from regressions including indirect effects.

Estimated Component	*Fuel Price*	*Income*	*Taxation (other than Fuel)*	*Population Density*
Car stock	-0.20 to 0.0 [-0.1]	0.75 to 1.25 [1.0]	-0.08 to -0.04 [-0.06]	-0.7 to -0.2 [-0.4]
Mean fuel intensity	-0.45 to -0.35 [-0.4]	-0.6 to 0.0 [0.0]	-0.12 to -0.10 [-0.11]	-0.3 to -0.1 [-0.2]
Mean driving distance (per car per year)	-0.35 to -0.05 [-0.2]	-0.1 to 0.35 [0.2]	0.04 to 0.12 [0.06]	-0.75 to 0.0 [-0.4]
Car fuel demand	-1.0 to -0.40 [-0.7]	0.05 to 1.6 [1.2]	-0.16 to -0.02 [-0.11]	-1.75 to -0.3 [-1.0]
Car travel demand	-0.55 to -0.05 [-0.3]	0.65 to 1.25 [1.2]	-0.04 to 0.08 [0.0]	-1.45 to -0.2 [-0.8]

Notes: Figures in brackets represent what the authors consider as the most reasonable magnitude of the estimates.
Source: Johansson and Schipper (1997)

The authors found that vehicle stock is heavily dependent on national income, with a long run elasticity of approximately 1.0. The estimated long run fuel price elasticity was small, about -0.1. The authors found that the long run tax elasticity was not the same in all countries, varying between 0.01 in the US to 0.13 in Denmark. The population density parameter implied that an increase of 10 citizens per km2 is associated with a long run decline in the vehicle stock of 0.4%.

For mean fuel intensity the results indicated a long run price elasticity of about -0.4. The influence of overall taxation was also significant, implying that a taxation increase of $1,000 would decrease mean long run fuel intensity by about 1%. The population density variable was also negative and significant with an elasticity of about -0.2. Income effects were not consistently determined.

The long run fuel price elasticity of mean driving distance was estimated at -0.2. Income and taxation effects were found to be positive and significant, and population density appeared to have a fairly strong negative influence on mean driving distance, with an estimated elasticity of -0.4.

The authors used their results from the three separate estimations to obtain results for long run car fuel and travel demand. They calculated a long run fuel price elasticity of approximately -0.7, in which the largest fraction was due to changes in fuel intensity. The figure was over double the estimated price elasticity on travel demand

The long run income elasticity on fuel demand was approximately 1.2, almost all due to the number of cars, and was of identical magnitude with respect to travel demand. The tax elasticity with respect to fuel demand was -0.11, but had no apparent effect on travel demand. The population density elasticity with respect to fuel demand was estimated at -1.0, and with respect to travel demand at -0.8.

In conclusion the authors drew the policy implication that a fuel tax increase would reduce overall long run fuel consumption much more than an increase in the other car related taxes, for example, taxing car ownership.

Fridstrøm [67] examined how aggregate car ownership and road use depended on income, interest rates, and travel costs including fuel and vehicle taxes. The data analysed were pooled cross-section time-series, defined by monthly observations for all counties in Norway for the period from January 1973 to December 1994. The author used a generalised variant of the Box Cox method to analyse car ownership, which allowed tests of whether price and income elasticities diminish or increase as the price or income level grows. A partial adjustment model was used to represent car ownership where the number of cars registered was assumed to adjust to an assumed equilibrium level. The demand for road use was specified in a standard Box-Cox regression. Fridstrøm examined the influence of price income and vehicle ownership variables, but he also included in the model variables pertaining to public transport supply, road infrastructure supply, demography, climatic variables and geographical characteristics.

[67] Fridstrøm, L (1998) 'An econometric model of aggregate car ownership and road use', Journal of Transport Economics and Policy, (forthcoming).

Fridstrøm's results estimated a long run income elasticity of demand for cars of 1.2 averaged over the sample, but which is slightly decreasing as income increases. The income elasticity of road use was estimated at 0.38, given car ownership, and was found to be increasing strongly enough to more than outweigh the decreasing income elasticity of car ownership. Road use was substantially more income elastic in the long run (when car ownership effects are incorporated) than in the short run. Fridstrøm estimates the total long run fuel cost demand elasticity at -0.24, and again the demand for road use was found to be much more elastic in the long than short run: the fuel cost elasticity of demand increases with the cost level.

Crawford and Smith [68] discuss the role of the taxation of road transport in encouraging air pollution abatement. The authors compare three main policy options: increases in the average level of motor fuel taxes, tax differentiation between different motor fuels or classes of vehicle, and the tax treatment of complements or substitutes to vehicles which cause pollution.

They showed that motor fuels are currently taxed substantially more heavily than other goods or other uses of energy in EU countries (table below).

Total Tax Rates (VAT and Excise Duty) on Leaded Petrol in European Union Countries in 1993.

	ECU per litre	*Proportion of Average Retail Price*
Belgium	0.59	72%
Denmark	0.47	64%
France	0.67	79%
Germany	0.59	74%
Greece	0.55	75%
Ireland	0.49	65%
Italy	0.65	75%
Luxembourg	0.44	67%
The Netherlands	0.67	73%
Portugal	0.59	73%
Spain	0.48	67%
UK	0.34	71%
Unweighted EU average	0.54	71%

Source: Crawford and Smith (1995)

[68] Crawford I and Smith S (1995) 'Fiscal instruments for air pollution abatement in road transport', Journal of Transport Economics and Policy, 29 (1), 33-51.

The authors point to the elasticity evidence from the literature, which shows that higher petrol prices will tend to have three main effects:

i. Reduction in vehicle use.
ii. Reduction in vehicle ownership.
iii. Higher fuel efficiency of the vehicle stock.

They point out that the effects on traffic levels and car ownership tend to be less than effects on fuel consumption. Thus, the authors argue that while the impact of changes to the general level of petrol taxes on fuel use emissions could be appreciable, much of the impact would come about through the size and fuel efficiency of vehicles rather than traffic levels. Tax differentiation in favour of unleaded petrol appears to have had a substantial effect and the authors state that there may be a case for differentiation to prevent an increase in the share of diesel powered vehicles. Finally, the authors state that the imposition of a package of fiscal measures, including higher parking charges and public transport subsidies, may be more effective at discouraging vehicle emission than policies that apply to fuel and vehicles alone.

Koopman [69] focused on the cost effectiveness of policy instruments to achieve reductions of CO2 emissions from transport. His analysis was based on a partial equilibrium simulation model for Europe that used different means to achieve a 10% reduction in CO2 emissions . He examined the impacts of:

Scenario 1: a fuel tax which involved a proportional increase in all excises by 42%

Scenario 2: a CO2 tax which increased in excises on the basis of CO2 content of fuel, petrol (20.9%), diesel (27.8%), and LPG (27.9%)

Scenario 3: an annual car owner tax that involved a proportional increase in all car ownership taxes by 470%.

His simulations examined different effects of these policy instruments as shown in the table below.

[69] Koopman GJ (1995) 'Policies to reduce CO2 emissions from cars in Europe: a partial equilibrium analysis', Journal of Transport Economics and Policy, 29 (1), 53-70.

Impacts of Various Policies to Limit CO_2 Emissions from Cars (as percentage difference from baseline levels in 2010/15)

	Scenario 1	*Scenario 2*	*Scenario 3*
CO_2 emissions	-10	-10	-10
Economy-wide welfare effects			
welfare effects to			
producers and consumers	-1.9	-1.8	-5.0
Government tax revenues	-4.3	-4.2	-22.7
	2.4	2.5	17.8
Fuel use per Kilometre	-7.1	-7.1	0.0
Costs of ownership	3.8	3.6	41.8
Costs of usage	6.9	6.7	0.3
Price of private transport	4.5	4.4	25.8
Car ownership -	3.6	-3.3	-18.4
Car usage (mileage)	-4.4	-4.3	-12.3
Use of public transport	3.2	3.1	17.6

Source: Koopman (1995)

Koopman noted that the impacts of proportional fuel taxes are very similar to those of a CO_2 tax. Both scenarios imply an increase in average fuel prices of more than 20%, with welfare costs of just less than 2% and fuel efficiency predicted to rise by 7%. Scenario three had greater welfare costs and was not predicted to increases fuel efficiency. The price of private transport rose under all scenarios but to a much greater extent under 3, and this is reflected also in the much higher predicted use of public transport under this scenario. Koopman concluded that carbon based taxes are superior to relying on increased car ownership taxes.

W S Atkins have recently completed a major study for the DETR [70] to evaluate transport measures in order to attain NAQS objectives. The report constructs and evaluates a very large number of options in a Vehicle Emission Strategy Matrix. It then assesses the potential reductions that may occur in NOx and PM10 emissions. London was used as the case study and estimates of the costs associated with different strategies are presented.
The report identifies three strategy types:

Demand Management (DM)

local transport measures to reduce amount of traffic, including road user charging, parking controls, improving public transport, etc.

Emission Control (EC)

reduction of pollution from vehicles by the use of alternate fuels and policies to enforce emission standards including Low Emission Zones (LEZ) and Inspection and maintenance programmes.

Combined DM and EC strategies

Summary of emissions reductions impacts for different strategy types.

Strategy	*NO_2 Central London*	*PM_{10} Central London*	*NO_2 City-Wide*	*PM_{10} City Wide*
Demand Management	4% to 7%	5% to 20%	1% to 10%	1% to 11%
Emissions Control				
- Alternative Fuels	14% to 44%	11% to 44%	4% to 37%	4% to 37%
- Low Emissions Zone	18% to 26%	14% to 23%	8% to 18%	6% to 17%
Combined Emission Reduction	25% to 72%	36% to 70%	10% to 51%	14% to 51%

Source: WS Atkins (1999)

The table shows that both demand management and emission control methods can achieve substantial reductions in emissions. The report went on to show that the implementation costs of achieving city wide emission reduction from Demand Management strategies (£7-197m per annum) is far greater than for emissions control methods (£100,000 to £1m per annum). Taking into account financial and non-financial costs, Demand Management strategies appear as more cost effective , but only because they are able to yield significant welfare benefits for non-health reasons. A great deal of uncertainty does, however, surround the true magnitude of these benefits.

Note, however that COMEAP has been unable to define the effects on health of NOx emissions [71] and when compared with the potentially low level of actual health benefits identified earlier, both strategies look costly as a way of improving health.

[70] W S Atkins DETR An evaluation of Transport Measures to meet NAQS Objectives

[71] COMEAP DoH: Committee on the Medical effects of Air Pollution: Quantification of the Effects of Air Pollution on Health in the United Kingdom

It would appear that Demand Management to reduce PM_{10} emissions cannot be justified on health grounds and should only be considered on the basis of the welfare benefits that they may provide in the form of lesser congestion and thus greater economic efficiency in the city.

Emissions Control using and enforcing existing legislation could bring worthwhile improvements in PM_{10} levels at moderate costs. But part of the EC strategies considered is for fuel replacement: this will improve local emissions but is likely to only displace the generation of CO_2 to other locations.

Conclusions on traffic management policies

There are a variety of demand management policies that can be pursued to attempt to reduce traffic use and fuel consumption. The effectiveness of these policies relies on a clear understanding of travel behaviour. Evaluation of their effectiveness has been marred by a lack of such understanding.

Note that the conclusions in this paragraph and the next relate to traffic at national levels and traffic in London will behave differently. Raising fuel price does have a noticeable effect on consumption. In the short run the price elasticity of fuel demand is around -0.3 and in the long run -0.8. This implies that motorists do find ways of economising on their use of fuel, given time to adjust. Raising fuel prices will therefore be more effective in reducing the quantity of fuel used than in reducing the volume of traffic.

The demand for owning cars is heavily dependent on income. The long run income elasticity of fuel demand is typically found to fall in the range 1.1 to 1.8. Short run income effects are between just less than a third and just over a half that size in magnitude: elasticities normally estimated in the range 0.35 to 0.55. The implication is that fuel prices must rise faster than the rate of income growth, even to stabilise consumption at existing levels.

For London, congestion charging, if it is implemented, is likely to have a more noticeable impact on local traffic volumes than fuel price based instruments. A major study of the potential congestion charging may offer to reduce traffic levels in London is in preparation and is expected to be published late in 1999. The effect on air quality would probably be small and this is also true of other traffic management measures – even though they may be highly beneficial for other reasons.

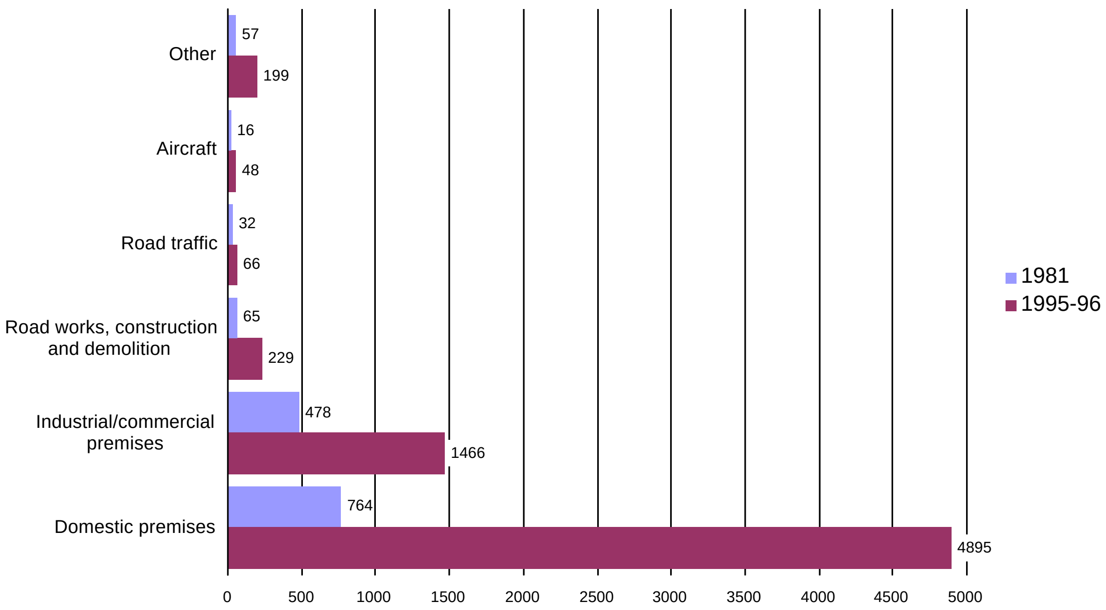
D 1 TRAFFIC NOISE and HEALTH

Noise and Vibration certainly cause problems for some individuals. However it is clear from the chart below that noise nuisance from road traffic is a comparatively minor irritant when compared with noise from other sources.

Complaints about traffic noise amount to only 1% of all noise related complaints made to environmental health officers in local authorities. It is also likely that most people living in cities such as London become well acclimatised to road noise and in any case know that there is very little that can be done to alleviate the problem.

Even when there is real nuisance it becomes an accepted fact of living in certain locations in the city.

Complaints to Local authorities about Noise Nuisance: 1981 - 1996



There is the matter of noise pollution caused by certain motorbikes. This is a real nuisance and existing legislation is in place to deal with the problem. However the matter of enforcement is always problematical when there are substantial other demands on Police time.

E 1 HEALTH ENHANCEMENT by TRANSPORT MEASURES

This report has concentrated largely on traffic generated pollution and the difficulty found positively linking it and identifying it as the major cause of ill-health, even in a congested metropolis such as London and even when it is clear that public opinion considers traffic and its associated pollution as a major risk to health.

However the 97% of deaths that occur over the age of 35 are caused primarily by circulatory disease, (heart failure or stroke). The incidence of these illnesses can be directly linked to the physical fitness of the individual.

Fitness promotion via transportation means:

- more walking
- more cycling
- more use of public transport, getting to the bus / train / tube and then changing mode if necessary involves physical effort

Achieving such modal shifts and changing personal attitudes towards car use would have to be a long term aim and would involve substantial investment, particularly in public transport improvements and in making cities more congenial and more safe for walking and cycling.

ANNEX 1

Calculation of Health Provision costs with the NHS

	£ m	£ m
Hospitals and Community Health Services		
Family Health Services (cash limited)	26,651	
Family Health Services (non cash limited)	8,664	
Expenditure on Health Provision		35,315
Capital Expenditures	1,539	
Department Administration		309
Central Services		627
Expenditure on Support Services		2,475
NHS Expenditure 1997-98		37,791

Allocation of Health Provision cost on the basis of pro rata population:

	population		
UK	58.8m	~£ 630 / head	
			£ m
Estimated London health budget		7.07m	4,242
Estimated Greater London health budget		10.7m	6,420

Average NHS treatment costs:

RTA death	£ 4,470
RTA admission and recovery	£ 9,440
Respiratory admission and recovery	£ 2,500

ANNEX 2

Atmospheric Pollution: Sources on the Web

1 The Netcen site:
www.aeat.co.uk/netcen/airqual/welcome.html

2 DETR website:
www.environment.detr.gov.uk/airq/aqinfo.htm

3 Atmospheric Research & Information Centre (at Manchester Metropolitan University):
www.doc.mmu.ac.uk/aric/arichome.html

The Science of Air Pollution & Acid Rain

01 What is Acid Rain?
02 History of Air Pollution in the UK
03 Changing Air Quality and Clean Air Acts
04 The Key Air Pollutants
05 Urban and Rural Air Quality Data in the UK
06 Major UK Air Pollution Emissions from Transport
07 Major UK Air Pollution Emissions from Power Stations & Industry
08 Current Air Pollution Emissions in UK
09 Deposition of Air Pollutants
10 Critical Loads
11 Urban Air Pollution in World Megacities

The Impacts of Air Pollution & Acid Rain

12 Impacts of Acid Rain on Buildings
13 Freshwater Acidification
14 Impacts of Air Pollution & Acid Rain on Farmland & Crops
15 Impacts of Air Pollution & Acid Rain on Vegetation
16 Impacts of Acid Rain on Soils
17 Impacts of Air Pollution & Acid Rain on Wildlife
18 Air Pollution and Human Health
19 Air Quality and Lichens

Managing Air Pollution & Acid Rain

20 The UK National Air Quality Strategy
21 Standards & Guidelines of the Major Air Pollutants
22 Monitoring & Modeling Air Pollution
23 International Co-operation to Reduce Air Pollution
24 Local Air Quality Management
25 Motor Vehicle Emission Controls: Technologies
26 Motor Vehicle Emission Controls: Fuel Types
27 Industrial Emission Controls: Sulphur Dioxide
28 Industrial Emission Controls: Nitrogen Oxide
29 Sustainable Transport & Air Quality
30 Reducing Air Pollution - How Can You Help?

4 The Air Quality Management site:
www.ifi.co.uk/ahs.htm

5 National Society of Clean Air and Environmental Protection (NSCA):
www3.mistral.co.uk/cleanair/index.htm

6 South East Institute of Public Health (SEIPH)
www.seiph.umds.ac.uk/envhealth/ehg.htm

7 Comeap www.doh.gov.uk/hef/airpol/airpolh.htm Site acting as a filing cabinet for the important Comeap work

8 Friends of the Earth pollution facts:
www.foe.co.uk/factorywatch/intros/pol_facts.html

9 Greenergy:
www.greenergy.com/index.html