Air Quality and Road Transport

Impacts and solutions

Executive Summary

Guy Hitchcock, Beth Conlan, Duncan Kay,
Charlotte Brannigan & Dan Newman
June 2014

RAC Foundation

The Royal Automobile Club Foundation for Motoring Ltd is a transport policy and research organisation which explores the economic, mobility, safety and environmental issues relating to roads and their users. The Foundation publishes independent and authoritative research with which it promotes informed debate and advocates policy in the interest of the responsible motorist.

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About the Authors

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Guy Hitchcock is a principal consultant at Ricardo-AEA with over 20 years' experience of transport and environmental issues. He has worked in both consultancy and academia and his expertise includes vehicle emissions modelling, low-emission vehicle technology, local air quality management and carbon reduction policy. Guy has worked on a range of national and international studies on transport technology and emissions, in relation to air quality and climate change policies. He is currently working with a number of local authorities on Low Emission Zones and Strategies. Previously he carried out air quality and carbon assessments of local transport plans, supported Defra in the review of local Air Quality Action Plans, helped develop the concept of Low Emission Zones in the UK, and played a key role in the development of a 'Heavy Duty Vehicle Emission Strategy for Abu Dhabi'.

Beth Conlan
Beth is a business manager at Ricardo-AEA responsible for Air Quality Modelling, Mapping and Assessment. She has over 20 years of experience of air quality management at the local, national and international level. She has been involved in over 200 air quality review and assessments for local authorities and is working for Defra in the review of local air quality management. Recently, Beth advised the European Commission on air quality management implementation and the review of the Air Quality Directive. Since 1998 Beth has been a trainer of air quality management to local authorities as part of the Chartered Institute of Environmental Health EMAQ training programme which is endorsed by the Institute of Air Quality Management. Most recently Beth has been working with Defra and the Health Protection Agency on communicating air quality issues to health protection professionals within local Health and Wellbeing Boards and she has been appointed to COMEAP (the Committee on the Medical Effects of Air Pollutants).

Charlotte Branningan
Charlotte Brannigan is a senior consultant for Ricardo-AEA with over seven years' experience in the transport and environment policy sector. Charlotte has recently been involved in projects for the European Commission on assessing options for greenhouse gas emission reductions from transport until 2050, and for the Committee on Climate Change on development of marginal abatement cost curves for the transport sector, and research on the abatement technologies for the shipping sector. Charlotte also has a wide range of experience in undertaking Strategic Environmental Assessment (SEA) and Sustainability Appraisal (SA) for both local and national plans and programmes. Alongside this she has experience of Health Impact Assessment, having carried out this role for a major transport scheme in London for Transport for London.

Duncan Kay
Duncan Kay is a senior technical consultant for Ricardo-AEA and has a background of 16 years' experience in the automotive sector, working as a research and development engineer developing new technologies to improve fuel economy and reduce emissions from passenger cars. Since leaving the industry he has spent the last five years advising and consulting on a wide range of transport issues, particularly analysis of the automotive industry and transport greenhouse gas emissions reductions. Duncan has led studies for the Low Carbon Vehicle Partnership, the European Environment Agency and the European Commission amongst others. In 2012, he completed a study for the Joint Research Centre of the European Commission examining the role of research and development in maintaining the competitiveness of the European automotive industry.

Dan Newman
Dan Newman is a consultant for Ricardo-AEA with over three years of experience on sustainable transport projects for both governments and the private sector. Dan recently co-authored the 2013 RAC Foundation's Powering Ahead: The Future of low-carbon cars and fuels report. He has particular expertise in battery/hybrid electric vehicles and natural gas fuelled vehicles. He has been involved in a range of work for the European Commission and has recently been instrumental in investigating the effect of environmental regulations and standards on vehicle prices. Dan has led tasks assessing the impact of ICT on the large-scale deployment of battery electric vehicles for the European Commission, and has modelled how natural gas can contribute to achieving cost-effective greenhouse gas emissions reductions across the European transportation sector.

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Disclaimer

This report has been prepared for the RAC Foundation by Guy Hitchcock, Beth Conlan, Duncan Kay, Charlotte Brannigan and Dan Newman. The report content reflects the views of the authors and not necessarily those of the RAC Foundation.

Foreword

Over the years there have been news stories about severe air pollution levels in the Far East – images depicting heavy pollution in Beijing come to mind – making it seem like a distant problem. But recent domestic episodes have served as a reminder that air pollution is also a real concern on our own doorstep: no sooner did the European Commission start legal proceedings against the UK in February 2014 for failing to meet the EU's air quality targets than news came from Paris that air pollution levels in the city had reached levels well above those recommended by the World Health Organization (WHO). Then in April there was a spate of headlines focusing on air pollution in London.

Poor air quality undoubtedly has negative effects – but of precisely what kind and to what extent? What leads to harmful air quality? And what can we do to reduce or mitigate the impact of bad air?

We commissioned Ricardo-AEA to review the latest evidence and address these questions. If there is one thing that this report shows, it is that whilst the issue of air pollution is complex, the evidence clearly shows that it is a major public health issue which needs careful consideration.

Although concentrations of some air pollutants – carbon monoxide and sulphur dioxide for example – have come down significantly over the past decade or so, current regulatory breaches relate to nitrogen dioxide (NO_2), generated from emissions of nitrogen oxides (NO_x), and particulate matter (PM), the latter both in its coarser PM_{10} form (particles with an average diameter of 10 micrometres or less) and the very fine $PM_{2.5}$ form (2.5 micrometres or less).

Where Local Air Quality Management Areas have been declared, road transport is the principal source of pollution, though domestic and background emissions also contribute to the problem. NO_x is mainly a by-product of fuel combustion, whilst PM results from fuel combustion as well as road, brake and tyre wear.

So what is the main culprit? In short: diesel engines. Whilst heavy-duty vehicles – buses and lorries – are still the main source of NO_x emissions, the contribution from diesel cars has increased rapidly over the last decade because of the 'dieselisation' of the car fleet.

This is a consequence of the focus on climate change. The automobile industry's response to the European average new car CO_2 emissions targets of

130 g/km by 2015 and 95 g/km by 2021 has been to make more diesel cars, as these are more fuel-efficient than their petrol counterparts. And greater fuel efficiency equals lower CO_2 emissions. Unsurprisingly, individual and fleet buyers have responded by choosing diesel, enticed not only by the prospect of reduced fuel costs, but also by lower rates of Vehicle Excise Duty and company car tax incentives, which both reward low-CO_2 options.

But as the report shows, this is not the whole story. The root of the problem lies in the fact that the official tests by which new vehicles are certified do not reflect real-world driving. This mismatch applies to both the emission of air pollutants and to fuel efficiency (and therefore CO_2), as both are measured on the same cycle. Technologies such as diesel particulate filters function well under test conditions, but when operating on the road, especially in towns and cities where speeds tend to be lower, there is a risk that they will not 'regenerate', that is the high temperature needed to burn off the collected particles will not be present. This is the case not only with the older Euro standards (Euro 3 and 4) but even the current Euro 5 standard; together, these make up the bulk of diesel cars on the road. The new Euro 6 standard appears to be more promising.

Whilst the majority of regulatory breaches are in relation to NO_2, from a health perspective the more concerning pollutant appears to be PM; it is the very finest particles ($PM_{2.5}$) which are the most worrying. Unfortunately there is much more to be learnt about these particles. To complicate matters, current EU standards – the ones we are already failing to meet – do not reflect the latest evidence put forward by WHO. The science is outpacing legislation.

Quantifying the impacts of air pollution is extremely difficult, but as this report notes it has been estimated that elimination of all human-generated $PM_{2.5}$ would increase UK life expectancy from birth by six months: this is a bigger impact than eliminating passive smoking or all road traffic accidents. Clearly this is an issue that needs tackling.

What, then, can be done about air pollution? The authors cite the three-pillar solution known as 'Avoid-Shift-Improve': *avoid* means cutting out motorised travel altogether; *shift* means getting people to switch from high-polluting modes to low-polluting ones; and *improve* is about reducing the harmful environmental impacts of vehicle technology.

The good news is that many behavioural policies – reducing excess speed, managing traffic volume and smoothing traffic flow – will not only improve air quality, but also cut CO_2 emissions, accidents and congestion. Access restrictions such as Low Emission Zones, if designed in the right way, can be effective, but care must be taken not to disadvantage lower-income groups disproportionately as it is these who are more likely to own older – and therefore more polluting – vehicles.

Modal shift can help too. However, we must not assume this is always the best option: moving people out of a fully loaded petrol hybrid car into a lightly loaded, old diesel bus operating in heavy traffic is unlikely to be the answer. Rather than adopting blanket measures, government should carry out proper analysis to ensure that the best solution is found for the specific context.

Technological solutions have the potential to deliver great benefits. In the short term, switching to petrol – a technology in which there is still great potential, mainly through turbocharging and engine downsizing, for improving fuel efficiency – will help. Better vehicle maintenance and eco-driving can also make a real difference. In the medium term, moving to natural gas and hybrid petrol electric vehicles – once there are a greater variety of more keenly priced options available, so that mass-market penetration can be achieved – will reduce air pollution further. Moreover, natural turnover of the fleet will lead to a growing number of vehicles on our roads that comply with the latest Euro standard (Euro 6). And in the longer term, ultra-low-carbon (for example, pure electric) vehicles will help in the fight.

Whatever happens, intelligent demand management, especially in urban areas, is going to be crucial because of the increased pressure on the road network caused by a recovering economy and a growing population. A well-designed scheme is both necessary and sufficient to secure improvements in air quality. One solution might be time- and place-variable pay-as-you-go charging, which both reduces harms and generates cash – yielding a net benefit to society. Obviously there are equitability considerations, but some of the revenue generated could compensate lower-income groups or in some way be used for the greater social good.

Many policies *are* going to cost somebody – whether road users or taxpayers – money. The calculations need to be done to ensure that the benefits they deliver stack up against the costs, not just in financial terms but also regarding loss of mobility.

Conclusions and recommendations

The following is a list of recommendations based on what we know so far. It is by no means exhaustive, nor should it be taken as the final word – it is intended to stimulate discussion amongst the public and decision-makers.

(1) There is a need for **more real-time measurement** of what is going on in the field. Prediction by modelling, whilst useful, has turned out to have limitations. In this field what happens at a fine grain is important; and the physics, chemistry and social behaviour at this scale is complex.

(2) A **scrappage scheme** for the dirtiest vehicles should be considered. Whilst expensive, it could prove worthwhile for government, the industry and consumers.

(3) History has shown that price incentives can really change behaviour. However, **fiscal instruments** such as fuel duty and Vehicle Excise Duty **should reflect the true cost to society** – air pollution, accidents, congestion, noise and so on – and not unnecessarily distort the market towards any particular technology or behaviour. We would like to see a proper calculation of these costs, and policies set accordingly.

(4) **Mitigation measures should apply when and where needed**. Blanket measures risk causing unnecessary compliance costs, and therefore rigorous evaluation of specific options must be undertaken. Air pollution is a systemic issue that requires a long-term approach – any short-term, drastic measure may have severe adverse effects.

(5) The current **drive cycle** (New European Driving Cycle, NEDC) and test procedure must be replaced by the Worldwide harmonized Light vehicles Test Procedure (WLTP) by 2017, as proposed by the European Commission. We recognise that it will be important to adapt the latest Euro and CO_2 standards accordingly, as the industry has high sunk investments in the current regime.

There is a great deal more to learn. The stakes are high and therefore it will be crucial to devote more resources to researching the evidence and improving the measurement of pollutants. Meanwhile, because of the nature of air pollution, the normal commercial domain cannot be expected to deal with the problems on its own. This must fall to government.

Stephen Glaister

Director, RAC Foundation

Executive Summary

"There are still major challenges to human health from poor air quality. We are still far from our objective to achieve levels of air quality that do not give rise to significant negative impacts on human health and the environment."

Janez Potočnik,
European Commissioner for the Environment (Potočnik, 2013)

Air pollution is a major issue of concern to the public and politicians, with the focus of attention being on poor air quality and way it affects the quality of life in urban areas. It is well recognised that road transport plays a significant part in air pollution in urban environments, and thus contributes to this public health issue.

This report reviews the latest evidence in relation to transport and air pollution, and aims to address three key questions:

1. What role does road transport play in relation to air pollution in towns and cities?
2. What is the health impact of this pollution, and what are the associated economic costs?
3. What are the main solutions for reducing air pollution from transport?

The contribution of transport to air pollution

The UK is failing to comply with European air quality limits in respect to nitrogen dioxide (NO_2) levels across most urban areas, and in particular at roadside locations. Levels of particulate matter (PM_{10} and $PM_{2.5}$; the subscript indicates the particle size in micrometres) are largely within the European limit values; however, the EU limit value is higher than the more stringent World Health Organization (WHO) guidelines. Therefore particulate matter (PM) is potentially a much more significant issue for public health than the compliance data alone might suggest. Overall, transport contributes some 30% of total nitrogen oxide (NO_x) emissions and 20% of total PM emissions, but these are concentrated on the road network in towns and cities, where the majority of air quality limit breaches occur, and where the population density is often high.

At the local level, breaches of the air quality limits have resulted in the declaration of some 600 Air Quality Management Areas (AQMAs) across the country. The vast majority of these have been declared for breaches of the NO_2 limit value, and in relation to road transport sources. The AQMAs cover the major cities, as might be expected, but also a wide number of much smaller areas such as local hotspots in market towns which have narrow congested streets. Thus the type and nature of the problems varies depending on the exact location and context.

In terms of NO_2 pollution concentrations, diffuse background pollution in urban areas ranges from 10 µg/m^3 to 30 µg/m^3, with road transport contributing around another 30 µg/m^3 to 50 µg/m^3 at roadside locations. This can give rise to pollution levels at twice that of the European limit values (40 µg/m^3). Although reductions in background concentrations achieved by tackling residential and commercial emissions will be important, major improvements will still have to be made in relation to emission from transport activity. In many roadside locations this will mean reducing transport emissions by at least 50%, and even by as much as 75–80% in some cases. Clearly this will be a significant challenge.

Heavy-duty trucks and buses are the main source of NO_x emissions, which contribute to NO_2 concentrations, but in absolute terms this has been reducing. Diesel cars are now the second-largest source of NO_x emissions, and this source has grown rapidly over the last 15 years. This indicates a potential conflict with climate change policy, which has to some degree supported the growth in diesel cars owing to their lower fuel consumption and CO_2 emissions.

Diesel vehicles are also the main source of PM emissions when it comes to road transport, but the difference in relation to petrol vehicle is much less than for NO_x, as PM emissions are also generated from brake and tyre wear and from road abrasion. Therefore PM emissions are not solely a diesel vehicle problem, and will require solutions that tackle non-combustion sources of pollution as well.

Moreover, levels of measured air pollution have improved little in recent years, despite progressively stricter vehicle tailpipe emission limits driven by European legislation. Estimated vehicle emissions have declined, but this has not resulted in significant improvements in local air quality. A mismatch between regulation and real-world NO_x emissions from diesel vehicles seems to be one of the key reasons why the expected reductions in NO_2 concentrations at the roadside have not materialised. This is further compounded by a growth in the share of diesel vehicles in the UK, and by the increase in direct NO_2 from newer diesel cars meeting Euro 4 and Euro 5 emissions legislation.

Understanding and putting a value on the impact of air pollution

There is clear evidence that there is a causal relationship between exposure to traffic-related air pollution and health impacts such as exacerbation of asthma, non-asthma respiratory symptoms, impaired lung function and cardiovascular mortality and morbidity (the frequency and severity of the condition in the exposed population). Overall, the strongest evidence for the most problematic pollutants in terms of human health is for particulate matter, especially fine particulate matter ($PM_{2.5}$) and ozone (O_3). NO_2 is also a key concern because of its direct health effects and also because it is a precursor to ozone formation.

Across Europe an estimated 20–30% of the urban population are exposed to $PM_{2.5}$ levels above EU reference values, and 91–96% are exposed to levels above the more stringent WHO guidelines. In the UK, the burden of particulate air pollution in 2008 has been estimated to be equivalent to nearly 29,000 premature deaths (at typical ages of death), and to an associated loss of population life of 340,000 life-years.

It has been calculated that if all anthropogenic $PM_{2.5}$ air pollution was removed, approximately 36.52 million life-years over the next hundred years could be saved in the UK. In addition, this elimination would be associated with an increase in UK life expectancy from birth (i.e. on average across new births) of six months. To put it into context, a study by the Institute of Occupational Medicine (Miller & Hurley, 2006) estimated that removing all fine particulate air pollution would have a bigger impact on life expectancy in England and Wales than eliminating passive smoking or all road traffic accidents.

Air pollution is therefore a major public health concern, and can be valued in terms of an economic cost. Across the EU, the economic cost of air pollution has been estimated to range between €330 billion and €940 billion per year in 2010, taking into account labour productivity losses and other direct economic damages. Similarly, in the UK the health impact of poor air quality has been calculated to cost between £9 billion and £19 billion per year (Defra, 2010). The transport contribution to this figure has been estimated at between £4.5 billion and £10.6 billion (at 2009 prices), in other words approximately half of the total.

In relation to other impacts of transport, air pollution ranks alongside excess delays, physical inactivity and accidents in terms of scale. Nevertheless, public concern in relation to transport air pollution seems to be waning, although this could be a consequence of heightened concern for the economic factors and cost of living following the recession that began in 2008.

Owing to its significant health impacts, air pollution – specifically $PM_{2.5}$ pollution – has been included as an indicator in the Public Health Outcomes Framework (PHOF) to be delivered by local authorities (DoH, 2013). This focus on PM in the PHOF contrasts with the focus on NO_2 compliance within the local air quality management (LAQM) framework.

Solutions to help reduce transport-related pollutant emissions

Transport activity is driven by a wide range of needs and behaviours, and has a range of impacts including congestion, air pollution, carbon emissions and accidents. Consequently there are a wide range of measures and actions that can be taken to influence travel patterns, mode choices and technologies with a view to reducing these impacts. Many of these measures are not designed primarily to reduce emissions or improve air quality, but are focused on reducing congestion; nevertheless, they will often help in the reduction of emissions, and can be enhanced so as to generate greater air quality benefits.

Much of the evidence on the air quality impacts and costs of these measures are indicative for several reasons:

- they have not been designed primarily to improve air quality, so this has not been directly assessed;
- they are often very locally specific, so it is difficult to draw clear results that are more widely applicable;
- there are still significant uncertainties as regards the effect of such measures on real-world vehicle emissions; and
- evidence on behavioural response to specific measures is still being gathered.

Demand management and behavioural change measures can be very cost-effective, as identified in the Sustainable Travel Towns demonstration, and can yield a wide range of benefits in the form of reduced congestion, improved air quality, reduced carbon emissions and increased levels of physical activity. However, our attitudes and habits when it comes to travel are very deep-rooted and can be hard to change, which means that significant and comprehensive packages of measures are needed to make a difference in the first place, and that thereafter maintaining this level of engagement has proved difficult. What is more, although significant impacts in terms of travel behaviour changes have been seen, these have not necessarily translated directly to improvements in air quality.

Traffic management and access control initiatives constitute a much more direct set of measures aimed at physically removing the source of the air pollution problem. As such they can be very effective, and when combined with redevelopment of an area – as has been done in Nottingham – can yield a wider ‘quality of place’ and economic benefits. On the other hand, they can be expensive to implement. Also, because of their restrictive nature they can be politically unpopular if not handled sensitively, which implies the need for considerable consultation and engagement.

The promotion of low-emission vehicles is the technology ‘fix’ that many favour as an alternative to changing behaviours. They can generate significant emission and air quality benefits if taken up substantially. However, they are not always as effective as expected, as has been shown to be the case with diesel emissions control, and many of the alternative technologies are still proving costly. Moreover, they do not provide the additional local benefits such as reduced congestion or increased levels of physical activity. However, at the national level they can provide economic benefits in terms of the development, production and servicing of new vehicle technologies.

These measures are not mutually exclusive – for example, a behaviour change programme can also be used to promote low-emission vehicles, and a bus quality partnership will generate improvements in overall bus services, assisting mode shift, as well as potentially improving the emission standards

of the buses. Moreover, none of these measures in isolation is likely to prove sufficient to solve air pollution problems: most measures will generate no more than something like a 5–10% reduction in emissions, whereas reductions of over 50% may be needed (as noted above). Therefore an integrated, comprehensive and potentially radical package of measures will be required if real improvements in air quality are to be seen.

The idea of a focused and integrated package of emission reduction measures is being taken up by some local authorities in the form of Low Emission Strategies. This integrated approach is also the thinking behind Sustainable Urban Mobility Plans at the European level (European Commission, 2011b), and to some degree local transport plans (LTPs) in the UK. To support such an integrated approach, the wider benefits of a more sustainable transport system need to be promoted, which will include effects in the spheres of air quality, climate change, health, noise, congestion and economic development. Indeed, Department for Transport guidance on LTPs states (DfT, 2009c):

> "It is important that LTPs are effectively coordinated with air quality, climate change and public health priorities – measures to achieve these goals are often complementary. Reducing the need to travel and encouraging sustainable transport can reduce local emissions, whilst improving public health and activity levels."

Summary recommendations

Transport is the greatest contributor to urban air pollution, specifically at roadside locations, which is where the highest levels of pollution exist and where significant exposure occurs. This in turn gives rise to a direct health impact associated with the traffic-related pollution. Substantial reductions in transport emissions, of 50% of more, are required to improve air quality and reduce pollution exposure at roadside locations sufficiently to comply with existing legislative standards. Evidence is also emerging to suggest that these legislative standards need to be tightened to adequately protect human health. The scale of this reduction in permitted limit values is very challenging, and to support further progress the following key policy recommendations are proposed:

At the European level

1. Consider tightening the regulated particulate matter limits, especially $PM_{2.5}$, in line with WHO guidelines, to reflect the greater health impact of particulate matter.
2. Assess the real-world effectiveness of Euro 6/VI legislation and include the proposed NO_2 limit.

At the national level

3. Adopt a more action-focused approach in the LAQM regime, and increase the focus on PM concentrations.
4. Strengthen the obligations of transport authorities in managing air quality, by making improving air quality a key priority for transport policy, alongside carbon reduction and economic growth.
5. Continue support for low-emission vehicles through the ultra-low-emission vehicle strategy and other mechanisms, but use a wider low-emission vehicle definition which considers both air pollutants and carbon emissions.
6. Provide national guidance and financial support for local measures to reduce transport emissions, including improved emissions data and tools, and wider evidence on the impact of measures.

At the local level

7. Integrate air quality considerations across all areas of local authority activity to provide a comprehensive and action-based approach to tackling air quality locally.
8. Consider the full spectrum of benefits from health and quality of life, from congestion and transport benefits to wider economic development, to assess the business case for transport measures.

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