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Non technical summary

Background

To improve air quality in London - which is currently among the worst in Europe - the Mayor and Transport for London (TfL) are proposing to designate Greater London as a Low Emission Zone (LEZ). The objectives of the proposed LEZ (commonly refered to as 'the scheme' in this report) are to further the aim of the Mayor's Transport and Air Quality Strategies by:

- Moving London closer to achieving national and EU air quality objectives for 2010
- Improving the health and quality of life of people who live and work in London, through improving air quality

Reducing the negative health impacts through improving air quality in London is the key driver for the introduction of the Low Emission Zone. In order to assess the potential health impacts arising from the possible implementation of the LEZ scheme, TfL has contracted AEA Technology and the Institute of Occupational Medicine (IOM) to undertake a full health impact assessment (HIA) of the proposal. The HIA will be made available during public and stakeholder consultation held between November 2006 and February 2007. This HIA will provide additional information supporting this consultation process.

It is well understood that the introduction of a LEZ could have direct and indirect impacts on health. In particular, the reduction in emissions due to tighter emission standards from vehicles included in the scheme is predicted to lead to improved air quality, and a reduction in associated health impacts.

This report describes the assessment of potential health impacts resulting from the proposed LEZ, summarises the key findings, and makes recommendations to TfL on how benefits can be maximised, how any negative impacts could be reduced, and how the health impacts of the scheme could be monitored.

The health impact assessment process

There is a range of health impacts that might arise from the implementation of the proposed LEZ scheme. A recognised means of assessing health impacts is through the use of an HIA, *a process that uses a range of methods and approaches to help identify and consider the potential – or actual – health and equity impacts of a proposal on a given population*.[1]

Health Impacts may include positive health benefits (e.g. a reduction in respiratory illness due to improvements in air quality) or negative impacts (e.g. an increase in stress and anxiety due to loss of employment resulting from increased costs relating

[1] NHS Health Development Agency (2002), *Introducing health impact assessment (HIA): Informing the decision-making process*, Published by NHS HDA, London

to compliance with a LEZ). TfL needs to be able to identify such impacts, and prioritise them in terms of significance. The potential positive health benefits and negative impacts provide one of the key criteria for evaluating whether the scheme should be implemented. In addition, the HIA should enable the scheme to be considered in order to maximise the benefits and minimise any undesirable impacts.

This report provides a set of evidence-based recommendations to TfL, highlighting the practical ways to enhance the positive benefits of the LEZ and to remove or minimise any negative impacts on health (including well-being) and to remove or minimise health inequalities that might arise or exist.

The Proposed London Low Emission Zone

Newer vehicles have much lower air pollutant emissions because of European legislation implemented over the past decade (known as Euro standards). It is possible to accelerate the introduction of these cleaner vehicles, and reduce the numbers of older, more polluting vehicles, through a **low emission zone** (**LEZ**). A LEZ is a defined area that can only be entered or driven within by specified vehicles meeting certain emissions criteria or standards, e.g. certain Euro standards. A LEZ prohibits older vehicles from operating in an area, and so accelerates the turnover of the vehicle fleet (or encourages the fitting of pollution abatement equipment which also leads to cleaner vehicles).

The proposed London LEZ scheme is being designed to discourage the use of the most individually polluting diesel-engined vehicles in Greater London by imposing a daily charge on vehicles which do not meet certain standards. These are generally older diesel-engine heavy-goods vehicles (HGVs), buses, coaches, heavier light-goods vehicles (LGVs) and minibuses.

What vehicles would be affected?
The LEZ would apply to both UK and non-UK registered vehicles. The vehicles to be included are based on European vehicle definitions to ensure a legal basis for the LEZ that applies equally to UK and European-based vehicles. A small number of vehicles would be exempt from the LEZ.

What are the proposed vehicle emission standards?
The proposed minimum emission standards for a vehicle to be able to drive within the LEZ without charge are as follows:

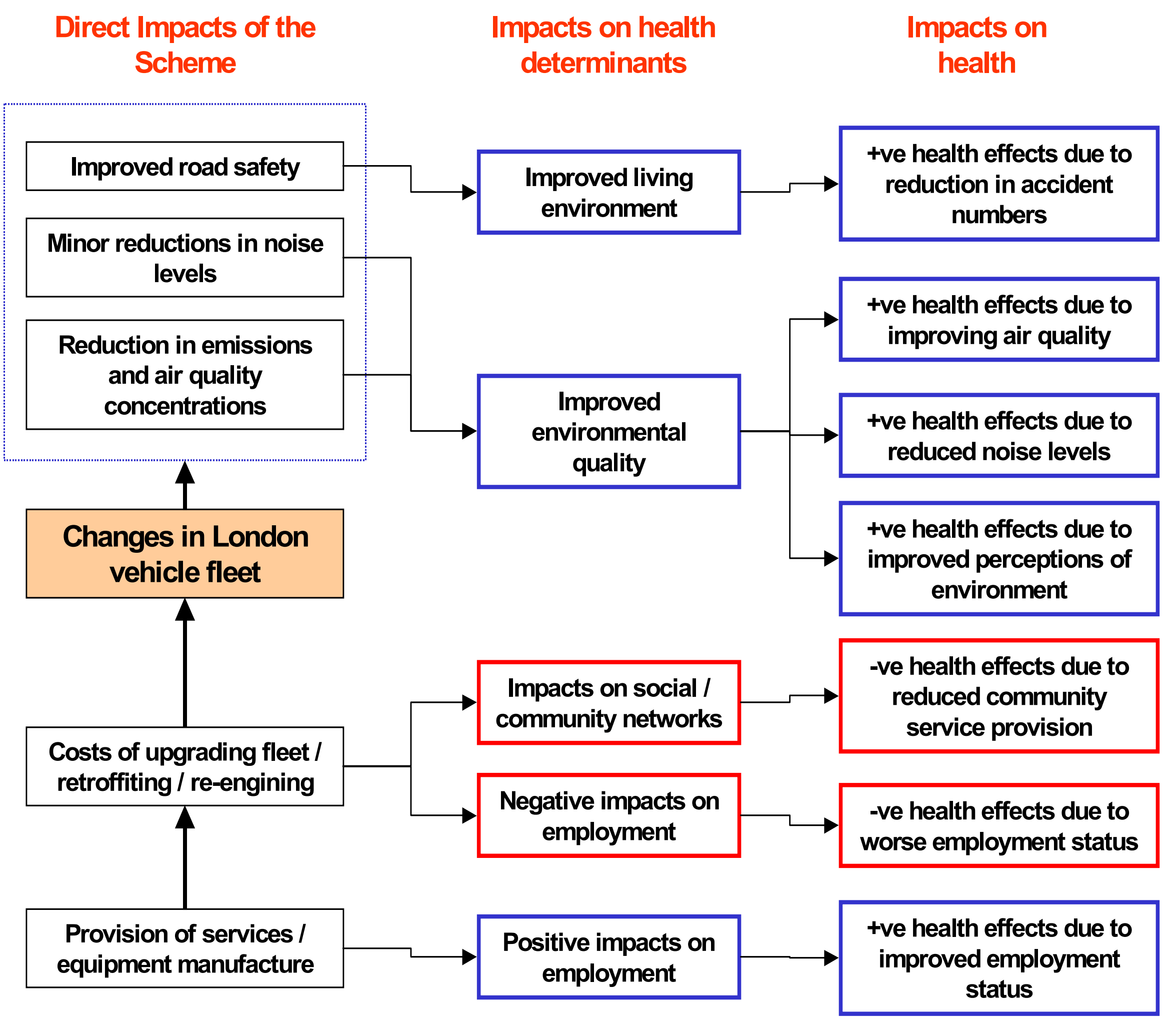
- From February 2008, a standard of Euro III for particulate matter (PM) for HGVs over 12 tonnes
- From July 2008, a standard of Euro III for PM for HGVs over 3.5 to 12 tonnes, buses and coaches
- From October 2010, a standard of Euro 3 for heavier LGVs and minibuses
- From January 2012, a standard of Euro IV for PM for HGVs over 3.5 tonnes, buses and coaches.

Appraisal of the evidence

Following the screening and scoping phases, the appraisal stage of the HIA considered the range of evidence for the potential health impacts of a proposal on the population's health. It involved investigating, appraising and reporting on how the proposal's implementation would be likely to affect health.

The scoping phase identified the main health effects and health inter-linkages of the proposed LEZ, illustrated below, and provided a focus for the full appraisal.

Anticipated health impacts associated with the possible implementation of the London Low Emission Zone



The left hand side of the figure shows the possible direct impacts of the proposed LEZ, covering both socio-economic and environmental impacts. The potential impact on factors affecting health (determinants), and subsequent impacts on health result from these direct impacts of the scheme. The analysis suggests that there may be an overall positive effect on health arising from the proposed scheme (as suggested by the previous HIA prepared for the Transport and Air Quality Strategy Revisions public and stakeholder consultation (ERM 2006). The appraisal phase of the HIA investigates the significance of the effects on health, and helps prioritise these impacts for TfL.

For this HIA of the proposed London LEZ, four key elements formed the basis of the appraisal stage.

Literature review. The literature was reviewed to consider the evidence of the impact of transport or air quality schemes on health, and the importance of health impacts associated with the LEZ proposal. The focus of the literature review was directed by the scoping phase and previous HIA analysis of the proposed LEZ. It included reviewing the literature of the following:

Air pollution and health:

- Evidence linking traffic emissions to adverse health effects, the nature of any health effects specifically associated with traffic pollution and by inference the health improvements that would be expected following a reduction in pollution exposure;
- The effectiveness of measures (LEZ or other) to reduce air pollution and other environmental improvements giving rise to measurable improvements in health;
- Information about which groups are potentially most vulnerable to the adverse effects of air pollution (and therefore who would be the most likely to benefit if the LEZ was implemented).

Perception of environmental quality:

- The importance of perception in determining the influence of environment on health and the extent to which a perceived improvement in environmental quality might lead to health benefits.

Socio-economic and other effects:

- The relationship between changes in socio-economic and/or employment status and health in order to understand the potential impacts on health that might arise if the LEZ were to adversely affect some businesses;
- Effects of noise and, therefore, the likely effects of a reduction in noise exposure on health;
- The potential impacts of improved road safety in reducing traffic accidents and the groups most likely to benefit.

In summary, the evidence in the literature indicates that different health effects could arise from the implementation of a LEZ, particularly due to the improvements in air quality.

Stakeholder engagement. The objective of this phase of the HIA was to help identify and prioritise potential health impacts, to understand how negative impacts can be minimised / positive benefits maximised, and to better understand stakeholder concerns on health issues. The engagement was facilitated by two workshops, which were attended by a broad range of health, transport and community stakeholders.

Overall, stakeholders were of the opinion that air quality would be beneficially changed by the LEZ and the perceived improvement in environmental quality would also be beneficial. These benefits could be maximised by integrating the introduction of the LEZ with other measures to encourage participation in walking and cycling, and to create a perception of improved environmental quality. The potential negative impacts of greatest concern was the impact on community transport and the potential for increased social isolation of vulnerable individuals including the elderly and disabled.

Community profile. The distribution of impacts is important to understand who would benefit most from positive health effects resulting from the scheme, and who may incur the greatest health disbenefits. The community profile focused on describing the distribution of air pollution and different types of communities affected.

Assessment of the proposal. Finally, based on the scoping phase, and the three appraisal methods shown above, a detailed assessment of the health impacts of the scheme can be developed. This assessment included consideration of the distribution of impacts. A summary of the overall findings is shown in he following section.

Summary of findings

Air quality

The health benefits modelling estimates that there would be important but relatively modest reductions in the health impacts associated with air pollution, and that the proposed LEZ would be an important part of London's overall strategy for improving air quality and limiting the associated health impacts. This is in evidence from the analysis of the reduction in the number of people in areas where concentration of NO_2 and PM_{10} exceed air quality objectives after the introduction of the LEZ, and from the quantification of estimated health benefits. It is important to stress that the health benefits would not be confined to London's population but to the wider UK population, due to the impact of cleaner vehicles used outside of the LEZ, as well as inside.

Using the health impact assessment methodology from the Defra Air Quality Strategy Review it is estimated that from 2005 to 2015, the emissions benefit in London from the LEZ will lead to 5,200 years of life lost gained, 43 respiratory hospital admissions avoided, and 43 cardiovascular hospital admissions avoided. Using the EC approach, a much greater additional health benefit is estimated on top of the benefits from extra years of life lost and avoided respiratory hospital admissions. It is estimated that around 310,000 cases of lower respiratory symptoms, 30,000 cases of respiratory medication use, and around 231,000 restricted activity days will be avoided from the introduction of the LEZ.

The total discounted benefits of the London LEZ schemes are estimated at approximately 200 million pounds using the Defra AQ Evaluation analysis and 420 million pounds using the EC CAFE CBA analysis. A significant proportion of these benefits result from air quality improvements outside of London.

There are significant differences in the distribution of these benefits. Central London boroughs appear to experience the highest level of benefit because that this is where the air quality problems are most severe. These boroughs are also those that have the highest proportion of deprived communities; therefore, it is the most deprived communities that on average experience the most significant improvements in air quality. Although the relative improvements in air pollution are modest, they are important given that such communities are thought to be more vulnerable to air quality impacts on health.

The most important health benefits from the proposed LEZ are those associated with improvements in air quality. The benefits estimated illustrate the important impact that the scheme would have on reducing the illness associated with air pollution in London.

Socio-economic Impacts

The economic and business impact assessment, prepared by Steer Davies Gleeve to support this public and stakeholder consultation of the proposed LEZ has estimated a small net cost to the London and south east economy, and a small loss in employment across certain sectors once the benefits to ancillary sectors have been taken into account. Based on this analysis, it is assumed that there would be a resulting small negative impact on health particularly due to impacts on employment. The distribution of the effects is probably more important given that there would be differences in the impact both between sector and within sectors. In particular, it appears to be the smaller businesses and those that are less able to pass costs through to the consumer that would be most affected. Sectors identified include construction and transport / storage / communications.

The compliance costs associated with replacing vehicles or retrofitting abatement technologies could have an impact on the ability of voluntary and public sectors to maintain a community services, whether this is transportation or a service that requires the use of vehicles affected by the scheme. At this time we cannot be sure to what extent these services would be affected by the scheme, if at all. It is recommended that TfL gather further insight through the consultation process.

Access to services is a particular issue for vulnerable groups, such as the elderly, disabled or most deprived communities, who have the greatest reliance. Any reduction in services could have implications for health, in terms of physical health (e.g. provision of healthcare or healthy food), and mental health and well being (e.g. participating in the community and use of local amenities).

Perceptions of the Environment

There is evidence that perception of environment can affect the health of the population, particularly in terms of well being, associated with how people view their quality of environment, and its impact on quality of life. Measuring this is difficult, particularly as perceptions within and between communities will differ significantly. On balance, it is likely that the health benefits from a changed perception of the environment would be relatively small.

The environmental improvement resulting from the LEZ might not be obvious. In which case the perception of improvements would only be likely through knowledge that a scheme was being introduced, and effective communication as to the likely benefits to health.

Noise

The evidence suggests that exposure to noise can have important effects on health. A LEZ has potential benefits on noise, as it removes older noisier vehicles from the fleet. However, it is estimated that the proposed LEZ would lead to only small reductions in noise levels; therefore, health benefits are likely to be marginal.

Road safety

Newer vehicles tend to be safer, and are part of the reason why road safety in the UK has improved. An increase in newer vehicles resulting from the proposed LEZ could lead to some small improvements in road safety, and a resulting small benefit to health.

We believe that the health impacts identified in this study can be prioritised on a relative basis, to provide guidance on which impacts are the most important in terms of evaluating the proposed LEZ on health. Prioritisation is based on our understanding of the magnitude of the impact, our confidence in the estimates, and the likelihood of the impact. In addition, the distribution of health impacts, particularly on the most vulnerable groups in London, can also be a factor in helping determine prioritisation.

Summary of health impacts associated with the proposed London LEZ

Impact on health determinant	**Benefit or negative impact to health***	**Relative prioritisation of impacts: - high, medium or low**	**Measurability / likelihood**
Improvements in air quality	Quantified reduction in years of life lost (mortality impacts) attributable to PM_{10} air pollution (including both primary particles from vehicle exhausts, and secondary particles generated from NOx emissions)	H	Calculated / Definite
	Quantified reduction in morbidity (e.g. respiratory hospital admissions, restricted activity days) attributable to PM_{10} air pollution (both primary and secondary particles).	H	Calculated / Definite
	Outside of London health benefits resulting from the use of LEZ compliant vehicles outside of the zone	H	Calculated / Definite
	Non-quantified health benefits associated with reduction in pollutants other than PM_{10} (E.g. direct impacts of NO_2 and ozone - quantification more difficult but possible with available pollution data)	M	Calculated / Definite
Access to services	Cost implications of the LEZ potentially leading to a reduction in community services, with implications for health, particularly those in most vulnerable groups	M	Qualitative / Possible
Employment status	The direct and indirect economic impacts of the proposed LEZ result in a small net financial cost; therefore, a small negative impact on health is assumed. The distribution of these impacts is potentially more important.	M	Qualitative / Probable
Perceptions of environmental improvement	Small health benefits could arise from people perceiving that the environment (in terms of air quality) is improving	L	Qualitative / Probable
Reduction in noise	Small positive health benefit associated with lower background noise levels due to increase in newer vehicles	L	Qualitative / Probable
Improved road safety	Small positive health benefit associated with fewer road casualties due to increase in newer, and therefore, safer vehicles	L	Qualitative / Speculative

* Benefits shaded green; negative impacts shaded orange

Recommendations

The following recommendations concerned with minimising any negative impacts and maximising health benefits have been proposed to Transport for London for their consideration, based on this HIA analysis.

1. The air quality health benefits are recognised as the key health effects associated with the proposed LEZ. It is therefore recommended that TfL further develop the methodology for assessing these benefits prior to the scheme's possible implementation. This recommendation is developed further in the section on monitoring.

2. The scheme currently proposed allows older vehicles to be fitted with PM abatement technology; there is no requirement to fit NOx abatement technology. However, the recent start of Euro IV heavy-duty vehicle emissions standards means that NOx abatement technology is developing rapidly. It is therefore recommended that TfL monitors these developments and at a future date reassesses the practicalities, costs and benefits of including NOx abatement within the LEZ scheme.

3. The health benefits that have been identified through the HIA and health benefits modelling work should be effectively communicated to the wider public, so that there is a wide understanding of health benefits associated with the possible introduction of a LEZ. This is also important for people's perceptions of the proposed LEZ, and could result in further health benefits.

4. The distribution of health benefits associated with air quality improvements could also be communicated – that the most deprived communities who are most susceptible to impacts from air pollution experience the largest reductions in pollutant concentrations.

5. The detail of the LEZ scheme should be widely publicised, particularly to the businesses and community organisations that might be affected. This should be done as soon as possible, to ensure that the cost implications of the LEZ can be managed before the introduction of the proposed LEZ. This could help minimise any negative health impacts that could result from job losses or reduction in community service provision. One way of achieving this for heavy goods vehicles (HGVs) would be for TfL to prepare, and VOSA to distribute, explanatory leaflets at the few HGV testing stations within and adjacent to London when vehicles are presented for their annual roadworthiness (MOT) test.

6. Community service providers, particularly those who provide services to vulnerable groups, should be encouraged to respond to the consultation to establish the potential impacts, and ways that impacts might be mitigated. This could minimise any disruption to services, and the potential associated health impacts.

7. Wider concerns on health raised through the HIA engagement process, and the other impact assessments, should be communicated widely to ensure awareness of the LEZ in different communities.

8. A monitoring strategy should be further developed to assess the actual health impacts of the LEZ post-implementation. This is discussed in greater detail in the following section.

Approach to monitoring

The impact of most measures targeting environmental improvement cannot be easily identified through health statistics because of the influence of many other factors on the population's health. This is likely to be the case with the proposed London Low Emission Zone, and therefore the collation of health statistics as part of a strategy to monitor the health impacts of the scheme has not been recommended here.

We propose that TfL collect a range of different baseline data prior to the date of implementation that enables them to 'estimate' the health impacts of the scheme. Depending on resources to undertake monitoring and the greater relative importance of some impacts, prioritisation for the collection of some data should be agreed. We propose four parts to the monitoring strategy for health impacts, with a focus on the health benefits resulting from air quality improvements.

Monitoring of health effects associated with air quality improvements
It has been recognised in this study that the main health benefits result from the improvements in air quality, resulting from lower emissions due to changes in the road vehicle stock in London. Analysis, as described in this report, can be further developed over the next few years to establish a more robust baseline prior to scheme introduction. The same analysis techniques can then be used to assess the impacts on health after implementation. Refinements to the current health benefits modelling could include the following:

- Improved emission inventories. It is understood that traffic monitoring is already underway to provide a significantly improved understanding of the vehicle profile across different parts of the London road network. This data will feed into the emission inventories, which are an important part of the input into air quality modelling, on which the health impact assessment is largely based.

  In addition, it will be important for new knowledge of emission factors, particularly across different euro standard vehicles, to feed into the emission inventory development. This may be achieved through continuing co-operation between London Atmospheric Emission Inventory (LAEI) and National Atmospheric Emission Inventory (NAEI) activities. However, uncertainty over appropriate emission factors for HGVs, particularly for Euro IV specification vehicles which only became mandatory from 1st October 2006, may mean that some further research is required.

- Improved pollution monitoring. It is understood that TfL has already expanded the pollution monitoring network, in particular to increase the measurements of $PM_{2.5}$. This is important because virtually all vehicle exhaust PM_{10} is actually $PM_{2.5}$, whereas the PM from tyre, brake and road wear, resuspension and from other non-road transport sources are predominantly in the $PM_{2.5}$ – PM_{10} range. Consequently, monitoring $PM_{2.5}$ is a more sensitive measure of PM from road transport exhaust, and will be a more sensitive measure of the effect of the LEZ on air quality. This additional data can then feed into the air quality modelling.

- Improved pollution modelling. It is important that advances in the understanding of techniques to model air quality pollution are incorporated into the methods used for the LEZ analysis.

- Refined health benefits modelling. There are number of ways that the health benefits modelling could be further developed over the next few years:
  - Quantification of health impacts associated with other pollutants
  - Incorporation of developments in quantification methodologies, including better characterisation of the impacts of different particle species
  - Improved knowledge of the patterns of daily population movement to more accurately model exposure

> We recommend that the health benefits modelling approach, and the methodologies for compiling the input data, are further developed over the next few years. This is important given that the key health benefits of the scheme are those relating to air quality improvements, and that such benefits are difficult to measure empirically.

For health affects associated with noise, these can be determined from the change in vehicle stock, which will be monitored. However, the impacts are likely to be small.

Impacts on employment and businesses and associated health effects
The HIA analysis suggests that health, particularly mental health and well being, can be affected by employment status. The proposed LEZ is likely to have a small negative impact on the levels of employment in certain sectors, notably construction and transport. This may be offset by new opportunities in manufacturing, fitting and maintaining pollution abatement equipment. Potential changes of employment resulting from the additional costs imposed by the proposed LEZ would be distributed differently across London's communities.

It is important that impacts on employment and businesses are monitored. From such information, it should be possible to assess qualitatively the relative importance of associated health impacts. Monitoring of the economic impacts of the Scheme is planned and the secondary health effects can be assessed based on such data.

TfL will put a monitoring strategy in place to assess the actual economic changes due to the LEZ, so will take into account the baseline situation without a LEZ. As part of this strategy, changes in employment will be identified. This information could be used to assess health benefits indirectly in sectors such as retrofitting, or selling new vehicles, and the additional revenues generated for the local economy. There may also be additional jobs associated with scheme implementation.

We recommend that the employment and business benefits and possible negative impacts are monitored through surveying or other relevant methods. The secondary health benefits can be qualitatively assessed from such monitoring data.

Impacts on access to community services and associated health effects

From the stakeholder engagement process, it was apparent that there are some concerns amongst providers of community services about the potential cost implications of the LEZ, and the impacts that this might have on the ability to provide services. The evidence suggests that the level of provision of community health-related services and other community based or public services that enable access to services by communities can impact on health.

We recommend that the levels of service provision across a range of public sector and voluntary service providers are monitored prior to the confirmation of the Scheme Order and following the introduction of the LEZ (should the Mayor confirm the Scheme Order). However, it is appreciated that it would not be appropriate to devote a disproportionately high level of resources at this, and consequently the monitoring would be at a semi-quantitative level.

Changing perceptions of the environment and associated health impacts

Perceptions of the environment can have limited impacts on well being and health. To monitor how perceptions of the environment, particularly air quality, change before and after possible LEZ implementation, surveys of different communities would be useful; many such surveys have been undertaken in the academic community. Such surveys could also identify differences in perceptions across London communities.

Changing perceptions are likely to be a factor of people's awareness of the scheme, particularly because physical changes resulting from the scheme are likely to be imperceptible. Research undertaken to assess the effectiveness of dissemination of information concerning the scheme, and the effectiveness of communicating the benefits of the LEZ could provide some indication as to general awareness about the scheme.

We recommend that some form of surveying is undertaken to consider people's perception of air quality before and after the scheme. From survey data, the implications of changing perceptions for health can be qualitatively assessed. For example, TfL may consider including some appropriate questions in the Londoner's Survey which is carried out several times a year.

In summary, we recommend that the focus of the monitoring strategy for health impacts is on refining the data inputs and methodology used in the health benefits modeling. This is because the primary health benefits of the scheme will be through improvements to air quality. A more robust methodology for this assessment is important in view of the lack of empirical data (e.g. changes in the incidence of illness) for use in monitoring. We also recommend that surveys are undertaken to enable assessment of health effects associated with socio-economic impacts and perception, although these are less of a priority.

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1 Introduction

1.1 BACKGROUND

To improve air quality in London - which is currently among the worst in Europe - the Mayor is proposing to designate Greater London as a Low Emission Zone (LEZ). The objectives of the proposed LEZ (commonly refered to as 'the scheme' in this report) are to further the aim of the Mayor's Transport and Air Quality Strategies by:

- Moving London closer to achieving national and EU air quality objectives for 2010
- Improving the health and quality of life of people who live and work in London, through improving air quality

Reducing the negative health impacts through improving air quality in London is the key driver for the introduction of the Low Emission Zone. In order to assess the potential health impacts arising from the possible implementation of the proposed LEZ scheme, Transport for London (TfL) has contracted AEA Technology and the Institute for Occupational Medicine (IOM) to undertake a full health impact assessment (HIA) of the proposal. The HIA will be made available during public and stakeholder consultation held between November 2006 and February 2007. This HIA will provide additional information supporting this consultation process.

It is well understood that the introduction of a LEZ could have direct and indirect impacts on health. In particular, the reduction in emissions due to tighter emission standards from vehicles included in the scheme is predicted to lead to improved air quality, and a reduction in associated health impacts. This is reflected in the Health Benefits Modelling that has underpinned much of the preceding analysis of the scheme. However, there are also other potential health impacts, many of which are indirect, and may result from socio-economic changes.

1.2 WHAT IS A HEALTH IMPACT ASSESSMENT?

There is a range of health impacts that might arise from the implementation of the proposed LEZ scheme. A recognised means of assessing health impacts is through the use of an HIA, *a process that uses a range of methods and approaches to help identify and consider the potential – or actual – health and equity impacts of a proposal on a given population* (NHS HDA 2002).

Health Impacts may include positive health benefits (e.g. reduction in respiratory illness due to improvements in air quality) or negative impacts (e.g. increase in stress and anxiety due to loss of employment resulting from increased costs relating to compliance with a LEZ). TfL needs to be able to identify such impacts, and prioritise them in terms of significance. The potential positive health benefits and negative impacts provide one of the key criteria for evaluating whether the scheme should be implemented. In addition, the HIA should enable the scheme to be considered in order to maximise the benefits and minimise any undesirable impacts.

The main output of the HIA should be a set of evidence-based recommendations to TfL, highlighting the practical ways to enhance the positive benefits of the LEZ and to remove or minimise any negative impacts on health (including well-being) and to remove or minimise health inequalities that might arise or exist.

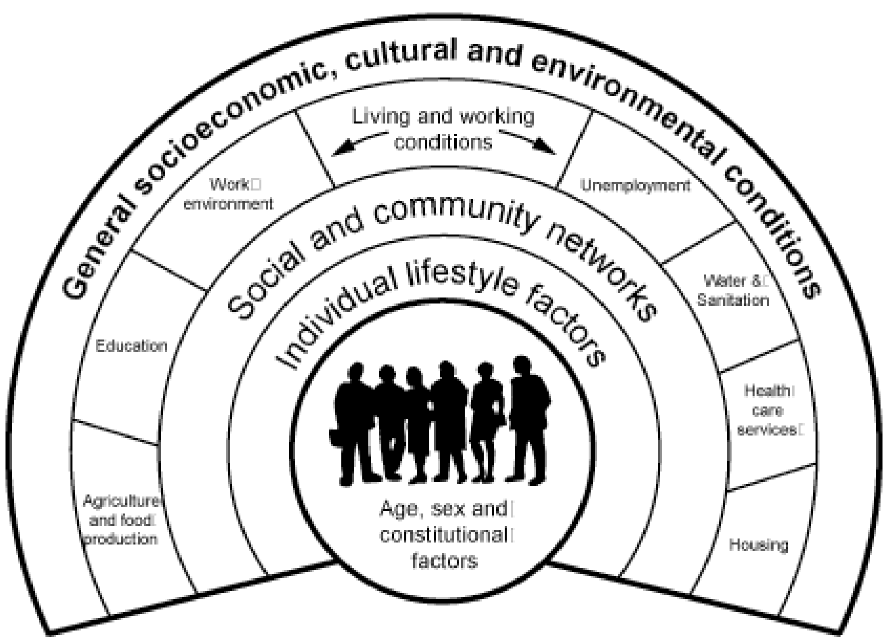
1.2.1 A broad model of health

An HIA is concerned with a socio-economic model of health, which considers the wider factors that might affect physical health, well being and inequalities. Such factors are known as *health determinants*, and include the following:

- Age, sex and hereditary factors
- Individual or family lifestyle factors
- Social and community networks
- Living and working conditions
- Socio-economic and environmental background

Figure 1.1 shows these determinants as layers of influence on the health of a population.

Figure 1.1 A socio-economic model of health (from Dahlgren and Whitehead 1991)



At the centre are individuals, characterised by age, sex and constitutional factors which influence health potential, but which are fixed. Surrounding the individuals are layers of influence that, in theory, could be modified, in this case by an air quality improvement scheme (for transport) such as a LEZ. The innermost layer represents the lifestyle adopted by individuals, including factors such as smoking and exercise levels, with the potential to improve or damage health. Individuals do not of course exist in isolation but interact with friends, relatives and their immediate community, and come under the social and community influences represented in the next layer. Support within a community can influence the health of its members. The wider influences on the ability to maintain health (shown in the third layer) include living and working conditions, food supplies and access to essential goods and services. Finally, there are general economic, cultural and environmental conditions prevalent in society as a whole, represented in the outermost layer (Acheson 1998).

It is important to stress the complexity of the interactions between the different determinants of health that lead to a specific state of individual health (or the health of the population in an area). The proposed LEZ might impact on different health determinants, leading to different health effects, both positive and negative. Identifying the impacts of a scheme can therefore be difficult given the many different influences on health. In particular, this makes the empirical monitoring of health impacts post-implementation of the scheme challenging.

1.2.2 The HIA process

The HIA process involves collecting a wide range of evidence in order to interpret health risks and potential health gains. There is no fixed method for undertaking an HIA; however, there is a broad consensus about the core stages that should be included.[2]

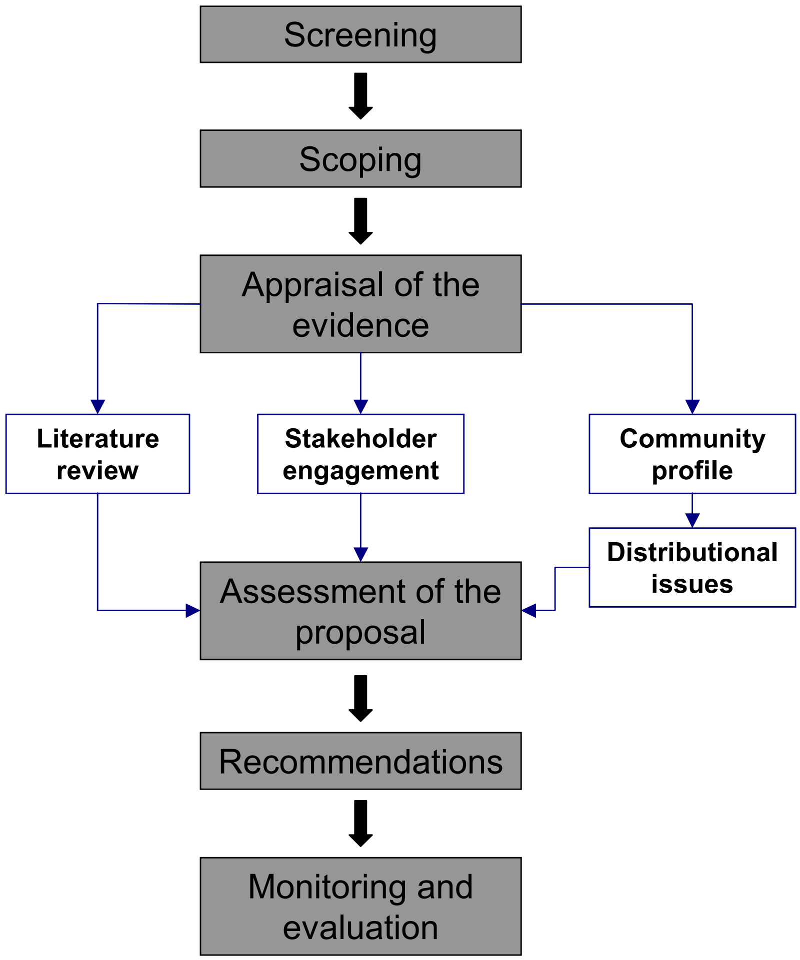
The core stages include:

- ***Screening*** – to decide whether an HIA is the best means of ensuring that health and equity concerns are addressed effectively
- ***Scoping*** – to decide how an HIA should be undertaken in the context of the proposal, in this case the London LEZ. The scoping phase has been completed, and discussed in section 3.2.
- ***Appraisal of evidence*** – to identify and consider the evidence for potential impacts on health and equity. This stage can use a variety of different methods for appraisal.
- ***Development of recommendations*** – to provide policy makers with an understanding of the key health impacts, and the means of enhancing positive effects / minimising any negative impacts
- ***Monitoring and evaluation*** - it is important that the actual impacts of the scheme are monitored to understand whether the implementation has led to the predicted health outcomes. In addition, it is important to evaluate the effect of undertaking an HIA, and consider whether the HIA process could have been undertaken more effectively.

[2] For this HIA, we have based our approach on the following guidance NHS Health Development Agency (2002), *Introducing health impact assessment (HIA): Informing the decision-making process*, Published by NHS HDA, London.

The type of HIA that is described in this report is *prospective*, in that it is being undertaken prior to possible implementation of the scheme (i.e. an ex ante appraisal), and can be considered to be at the *intermediate* level of detail.

Figure 1.2 The HIA process for London LEZ proposal



The core of the HIA is the appraisal of the evidence concerning health, and how this shapes our understanding of the potential health impacts – as reflected in the *assessment of the proposal*. Out of this core analysis, recommendations can be made to TfL concerning the health impacts and benefits of the scheme, and ways in which these can be monitored post-implementation. This report has been structured to reflect the above HIA process, and ordered accordingly.

2 The proposed London Low Emission Zone

A key element of the HIA process is the examination of the proposal for which an HIA is to be undertaken, and consideration of how such a proposal might affect the health of the population. In this section, we examine how the LEZ for London would be implemented, what the impacts on the road vehicle fleet would be, and in turn the reduction in emissions.

2.1 WHAT IS A LOW EMISSION ZONE (LEZ)?

Newer vehicles have much lower air pollution emissions because of European legislation implemented over the past decade (known as Euro standards). It is possible to accelerate the introduction of these cleaner vehicles, and reduce the numbers of older, more polluting vehicles, through a **low emission zone** (**LEZ**). A LEZ is a defined area that can only be entered or driven within by specified vehicles meeting certain emissions criteria or standards, e.g. certain Euro standards. A LEZ discourages certain polluting vehicles from operating in an area on the basis of their emissions, and so accelerates the turnover of the vehicle fleet (or encourages the fitting of pollution abatement equipment which also leads to cleaner vehicles).

Although traffic volumes do not necessarily change, a higher number of the vehicles travelling in an area are cleaner vehicles with lower emissions, and this leads directly to air quality improvements. Low emission zones for freight vehicles have already been successfully implemented and run for many years in Scandinavia, in Stockholm, Gothenburg, Malmo and Lund, where they have led to improvements in air quality levels (Watkiss et al 2003). They are also being widely considered by other UK and European cities, such as Sheffield, Liverpool, Oxford and Bristol.

2.2 THE CURRENT LONDON LEZ SCHEME PROPOSAL

The London LEZ scheme is being designed to discourage the use of the most individually polluting diesel-engined vehicles in Greater London by imposing a daily charge on vehicles which do not meet certain standards. These are generally older heavy-goods vehicles (HGVs), buses, coaches, heavier light-goods vehicles (LGVs) and minibuses. This HIA is being undertaken on the current proposal from TfL, the details of which are outlined in the Scheme Order and supplementary information.

2.2.1 What vehicles would be affected?

Table 2.1 indicates the types of vehicles included in the LEZ, the date of inclusion and the minimum emission standard the vehicle would have to comply with in order to drive within the LEZ without having to pay the daily charge.

Table 2.1 Vehicles to be included in the London LEZ Scheme

Vehicle type	Definition	European vehicle classification	Date of LEZ scheme inclusion	Minimum emission standard (for PM)*
Heavier HGVs	Goods vehicles exceeding 12 tonnes (gross vehicle weight)	N_3	February 2008	Euro III
Lighter HGVs	Goods vehicles between 3.5 and 12 tonnes (gross vehicle weight)	N_2	July 2008	Euro III
Buses and coaches	Passenger vehicles with more than 8 seats plus the driver's seat and exceeding 5 tonnes (gross vehicle weight)	M_3	July 2008	Euro III
All HGVs, buses and coaches	All vehicles as above.	N_2, N_3	January 2012	Euro IV
Heavier LGVs	Goods vehicles between 1.205 tonnes (unladen) and 3.5 tonnes (gross vehicle weight)	N_1 – class II and class III	October 2010	Euro 3
Minibuses	Passenger vehicle with more than 8 seats plus the drivers seat below 5 tonnes (gross vehicle weight)	M_2	October 2010	Euro 3

* There are two types of European emission standards – heavy duty standards for engines fitted to vehicles over 3.5 tonnes and light duty standards for engines fitted to vehicles below 3.5 tonnes. The LEZ would include vehicles with engines approved to either the light duty or heavy duty emission standards as per the Table 2.1.

The LEZ would apply to both UK and non-UK registered vehicles. The vehicles to be included are based on European vehicle definitions to ensure a legal basis for the LEZ that applies equally to UK and European-based vehicles. A small number of vehicles would be exempt from the LEZ. These include construction machinery, agricultural vehicles, military vehicles and historic vehicles (registered before 1973) not used for commercial activities. A further small number of vehicles would be outside the scope of the LEZ, as their emissions are regulated by other legislation. These include some construction machinery.

2.2.2 What are the proposed vehicle emission standards?

The proposed minimum emission standards for a vehicle to be able to drive within the LEZ without charge are set out in the table above and are as follows:

- From February 2008, a standard of Euro III for particulate matter (PM) for HGVs over 12 tonnes
- From July 2008, a standard of Euro III for PM for HGVs over 3.5 to 12 tonnes, buses and coaches
- From October 2010, a standard of Euro 3 for heavier LGVs and minibuses
- From January 2012, a standard of Euro IV for PM for HGVs over 3.5 tonnes, buses and coaches.

The LEZ scheme would be based on European vehicle emission standards, which are a set of requirements which define the acceptable limits for exhaust emissions for new vehicles sold in EU Member States. All HGVs, buses and coaches bought new in Europe since October 2001 comply with the Euro III standard or a higher Euro standard. All new LGVs sold in Europe from January 2001 must comply with at least the Euro 3 standard. All new HGVs, buses and coaches sold in Europe from October 2006 and all new LGVs sold in Europe from January 2006 will be required to comply with at least the Euro IV and Euro 4 standards, respectively.

All vehicles included in the scheme would be required to comply with the LEZ emission standards for PM. There are no plans to extend the emissions standards of the LEZ to include emissions of oxides of nitrogen (NO_x) at this stage; however TfL is continuing to consider how a NO_x standard might be implemented and could consider moving to implement a NO_x standard in future should this become feasible.

2.2.3 How could vehicle operators comply?

Under the proposed LEZ, operators would have a range of options available to them for making their fleets compliant with the LEZ, such as replacing or re-engining their vehicles, fitting particulate abatement equipment or reorganising their fleets so that only compliant vehicles operate within the LEZ. The costs of each option are dependent on vehicle type. The cost of fitting particulate abatement equipment to meet Euro III for PM ranges from £3,000 to £5,000 for HGVs, buses and coaches and £1,000 to £2,000 for LGVs and minibuses.

2.2.4 How would the LEZ scheme work?

A daily charge of £200 is proposed for non-compliant HGVs, buses and coaches to drive in the LEZ, and £100 for non-compliant LGVs and minibuses. The level of charge has been set to provide an economic incentive for operators to clean up their fleets, while at the same time allowing operators of non-compliant vehicles to drive within the LEZ on an exceptional basis, albeit at a cost.

Should an operator of a non-compliant vehicle not pay the daily charge for driving within London, a penalty charge would apply. This would be £1,000, reduced to £500 if paid within 14 days for HGVs, buses and coaches and £500, reduced to £250 if paid within 14 days, for heavier LGVs and minibuses.

Vehicles driving within the LEZ would be detected using fixed and mobile cameras. The LEZ would use Automatic Number Plate Recognition (ANPR) cameras. The LEZ enforcement infrastructure would be made up of a combination of the existing Congestion Charging cameras, additional fixed cameras located across the Greater London area and mobile patrol units also fitted with ANPR cameras.

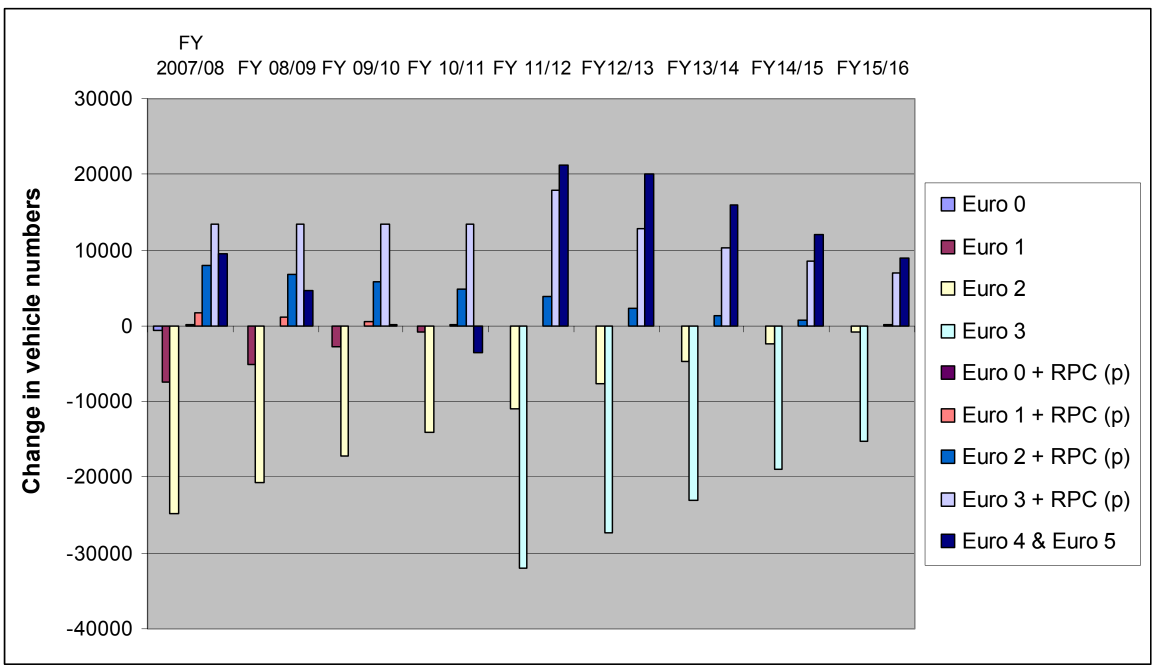
2.3 PREDICTED IMPACTS OF THE LONDON LEZ SCHEME

The primary impact of the LEZ scheme would be an impact on the vehicle fleet, which would in turn lead to changes in the level of emissions both inside and outside of London.

2.3.1 Changes in fleet profile

Figure 2.1 illustrates the expected change in vehicle fleet composition (for HGVs) due to the LEZ up to 2015. The significant differences relative to a *without LEZ* scenario is the significant increase in HGVs with retrofitted particle traps, and the reduction in Euro 2 and 3 vehicles without such retrofitted technology.

Figure 2.1 Projected change in HGV type resulting from LEZ introduction based on 2012 scheme characteristics



Source: LEZ Operator Cost Model, Transport for London (October 2006)

2.3.2 Emission reductions projected to result from LEZ scheme implementation

The changes in fleet composition have significant impacts on the level of road transport emissions. The reduction in emissions of NOx in specific years of the proposed LEZ is shown in Table 2.3. Table 2.2 shows the level of emissions without the introduction of a LEZ. The introduction of the Euro IV standard from January 2012 leads to larger relative reductions than seen in other years. This is because the Euro IV standard vehicles emit 30% less NOx than the Euro III standard. In addition, assumptions about changes to the fleet e.g. vehicle upgrades rather than retrofit mean greater reductions at this stage of the scheme.

Table 2.2 NOx emissions (tonnes) in selected years with no introduction of a LEZ

Area*	2008	2010	2012	2015
CCS	922	776	738	646
Inner	6,525	5,339	5,026	4,347
Outer	14,047	11,356	10,702	9,251
External	12,358	9,582	8,892	7,391
Total	**33,851**	**27,054**	**25,358**	**21,634**

* CCS is the congestion charging scheme area; Inner is the area between the London North-South circular (NSC) ring road and CCS area; Outer is the area between the London NSC and Greater London boundary; External is the area between the Greater London boundary and M25 (inclusive of the M25).

Table 2.3 Projected reduction in NOx emissions (tonnes) in selected years of the proposed LEZ

Area*	2008	2010	2012	2015
CCS	24	17	49	21
Inner	210	135	414	166
Outer	491	285	964	380
External	564	228	1047	391
Total	**1289**	**664**	**2474**	**957**
% emission reduction	3.8%	2.5%	9.8%	4.4%

* CCS is the congestion charging scheme area; Inner is the area between the London North-South circular (NSC) ring road and CCS area; Outer is the area between the London NSC and Greater London boundary; External is the area between the Greater London boundary and M25 (inclusive of the M25).

The data on the amount of PM_{10} emissions prior to introduction of a LEZ, and the predicted reduction due to the proposed LEZ are shown in Table 2.4 and Table 2.5.

Table 2.4 PM_{10} emissions (tonnes) in selected years with no introduction of a LEZ

Area*	2008	2010	2012	2015
CCS	71	63	61	58
Inner	554	496	487	467
Outer	1,143	1,031	1,016	978
External	695	595	578	538
Total	**2,462**	**2,184**	**2,142**	**2,042**

* CCS is the congestion charging scheme area; Inner is the area between the London North-South circular (NSC) ring road and CCS area; Outer is the area between the London NSC and Greater London boundary; External is the area between the Greater London boundary and M25 (inclusive of the M25).

Table 2.5 Projected reduction in PM_{10} emissions (tonnes) in selected years of the proposed LEZ

Area*	2008	2010	2012	2015
CCS	1	2	3	1
Inner	12	14	26	9
Outer	25	29	57	19
External	25	20	54	18
Total	**64**	**64**	**141**	**47**
% emission reduction	2.6%	2.9%	6.6%	2.3%

* CCS is the congestion charging scheme area; Inner is the area between the London North-South circular (NSC) ring road and CCS area; Outer is the area between the London NSC and Greater London boundary; External is the area between the Greater London boundary and M25 (inclusive of the M25).

Reductions in emissions would lead to improvements in air quality. However, the reduction in emissions and air quality is not linear as air quality depends on the quantity of pollutants emitted, chemical processes in the atmosphere, and the weather. The nature of the prevailing weather conditions can impact significantly on air pollution levels. The other key contributing factor affecting total ambient concentrations of pollutants in London is trans-boundary pollution. Air pollution, particularly particles and ozone (including precursor species for secondary particles and ozone) can be transported by air masses drifting from other parts of the UK, Europe or elsewhere; this can also adversely impact on ambient pollution levels experienced in London.

3 Screening and scoping

3.1 SCREENING

The first two stages of the HIA process are screening and scoping. The screening phase involves consideration of whether an HIA is the best approach to assessing health and equity issues, and deciding whether one should be undertaken. TfL has undertaken this stage, deciding that an HIA exercise is required, based on the potential health impacts that might arise from the scheme's implementation.

3.2 SCOPING

The scoping phase is critical to the HIA process, defining the boundaries of the assessment for a given proposal, defining the aims and objectives, the practical issues concerning undertaking an HIA, and any specific areas of focus. This phase was also important to understand the overlap with other studies that were being undertaken, including the Environmental Report, Economic and Business Impact Assessment and Equalities Impact Assessment (EqIA). An HIA scoping phase report was submitted to TfL in September (AEA Technology 2006), describing the scoping phase in detail.

3.2.1 Issues covered and agreed in the scoping phase

The following issues were covered by the scoping phase:

- The type of HIA that would be undertaken, and the boundaries of analysis
- An examination of the proposal, and an initial review of the potential health impacts
- The types of appraisal methods that would be used for this HIA, to include a literature review, stakeholder engagement exercise, community profile, and detailed examination of the proposal to consider the health impacts
- The type of analysis that would be undertaken to assess the health impacts
- The type of spatial assessment that would be undertaken, and the vulnerable groups that would be the focus of this assessment

In addition, the synergies with other assessment being undertaken were explored, in particular the EqIA, and the Economic Impact Assessment. The EqIA, undertaken by TRL (2006), has focused on considering the impacts (health, employment, economic) of the scheme across Equality Target Groups, whilst the focus of the Economic Assessment, undertaken by SDG (2006), was on employment impacts and the impacts on business and other organisations.

Both studies, in particular the EqIA by its nature, were considering the distribution of impacts. It was agreed that this analysis would feed into the HIA, although this HIA proceeded independently of the other studies in undertaking analysis of the distribution of health impacts.

3.2.2 Preliminary assessment of health impacts

A preliminary assessment of the potential impacts was undertaken in the scoping phase, and provided the basis for the different appraisal exercises that have been undertaken (see Section 4).

In addition, a significant amount of work has already been done to assess the health impacts of the proposed LEZ, in particular:

- The Phase 2 London LEZ feasibility study (Watkiss et al. 2003)
- Health benefits modelling under phase 3 and 4 to quantify benefits from air quality improvements (Watkiss and Pye 2006a; Watkiss and Pye 2006b).
- The previous HIA undertaken in support of the Transport and Air Quality Strategy Revisions consultation (ERM 2006)

In addition, other HIA studies provided a useful resource for an initial determination of the probable health impacts e.g. HIA of the Congestion Charging Scheme Western Extension (LHO 2005).

The following health impacts were identified at the scoping stage of the HIA process:

- Direct health benefits associated with air quality. The main purpose of the LEZ is to reduce emissions from the most polluting vehicles, and therefore the main health benefits are predicted to be associated with improvements to air quality.
- Health benefits associated with reduced noise levels. A small benefit is predicted from marginal reductions in noise pollution due to the increase in newer vehicles.
- Perceptions of environmental improvement. Greater feeling of well being could arise from people's perception that environmental quality is being improved with the introduction of a LEZ.
- Employment status and the implications for health. An economic impact assessment is being undertaken which should help determine the likely impacts on employment. Employment status can have an impact on well being and mental health – therefore, any impacts on employment may also lead to health impacts.
- Community access to services. With the inclusion of heavier LGVs and minicabs under the proposed scheme in 2010, the impacts on community services that use such vehicles could be affected (access to services) and indirectly lead to impacts on community health. Such community services include transportation for disabled, low income, elderly and youth groups, public transport services, library services, and other community service groups.
- Fewer road traffic accidents. A small benefit might come from the introduction of a LEZ due to the increase in newer vehicles, which have improved safety features, both reducing the number and severity of road traffic accidents.

In addition, the importance of understanding the distribution of these impacts across Greater London (and if possible outside of Greater London) was highlighted. There might be sectors of society and different communities who realise much greater benefits due to where they live (or who receive disproportionately greater negative impacts). These issues need to be explored to examine the distributional effects of the policy, and to investigate if the proposal will reduce or increase existing health inequalities.

4 Appraisal of the evidence

4.1 INTRODUCTION

The appraisal stage of the HIA considers the range of evidence for the potential health impacts of a proposal on the population's health. It involves investigating, appraising and reporting on how the proposal's implementation is likely to affect health. The health impacts (positive and negative - benefits and disbenefits) of a proposal are identified by various research methods.

For this HIA of the proposed London LEZ, four key elements formed the basis of the appraisal stage, on which the likely health impacts were identified.

1. **Literature review**. This is an important element of the HIA, in which the literature is reviewed to consider the evidence of the impact of transport or air quality schemes on health, and the importance of health impacts associated with the LEZ proposal. The focus of the literature review is directed by the scoping phase and previous HIA analysis of the proposed LEZ.

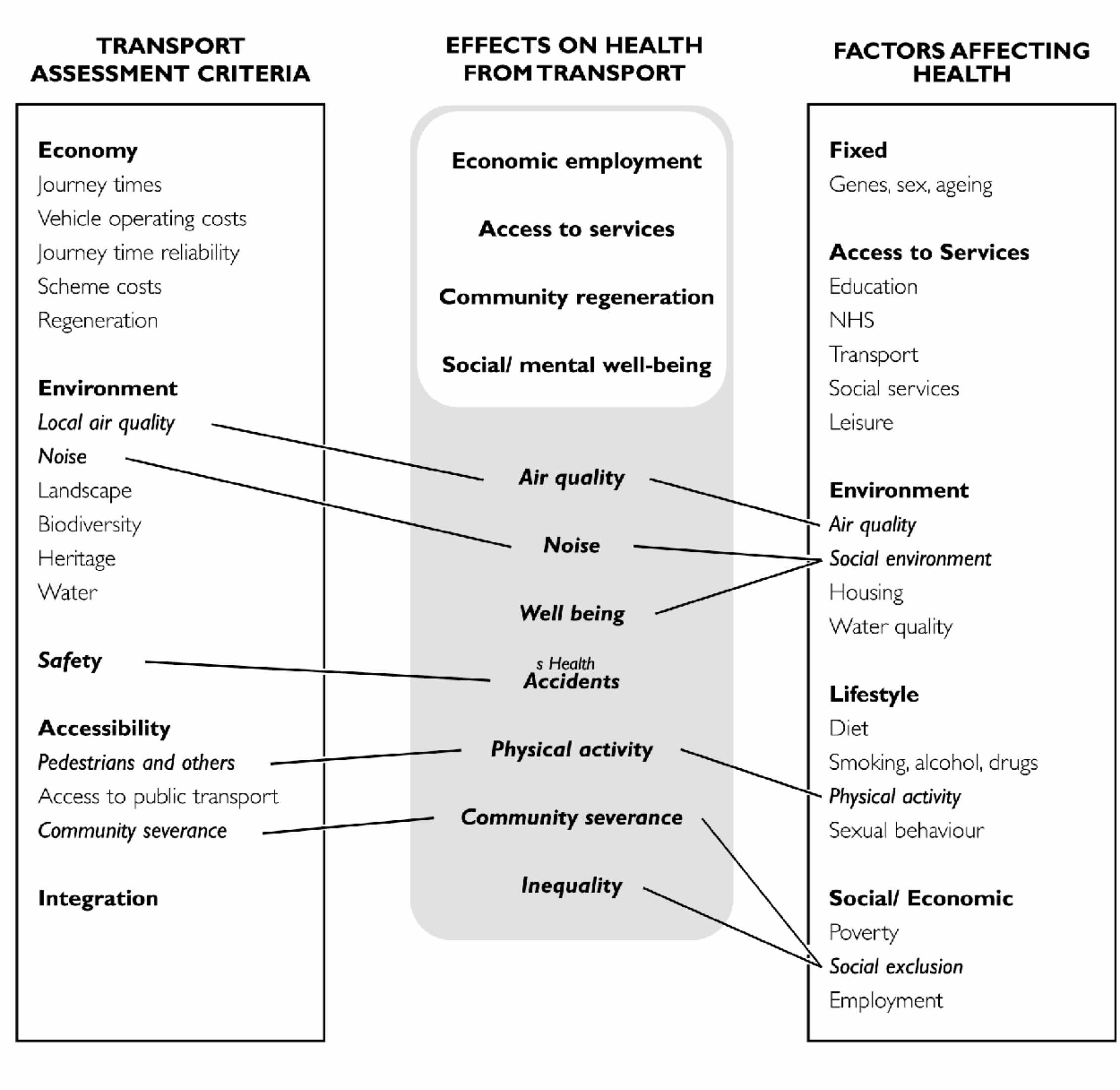
2. **Stakeholder engagement**. The objective of this phase of the HIA process is three-fold; to help identify and prioritise potential health impacts, to understand how any negative impacts can be minimised / positive benefits maximised, and to better understand stakeholder concerns on health issues.

3. **Community profile.** The distribution of impacts is important to understand who would benefit most from positive health effects resulting from the scheme, and who may incur the greatest health disbenefits.

4. **Assessment of the proposal**. Finally, based on the scoping phase, and the three appraisal methods shown above, a detailed assessment of the health impacts of the scheme can be developed. This assessment includes consideration of the distribution of impacts. This assessment can be found in section 5.

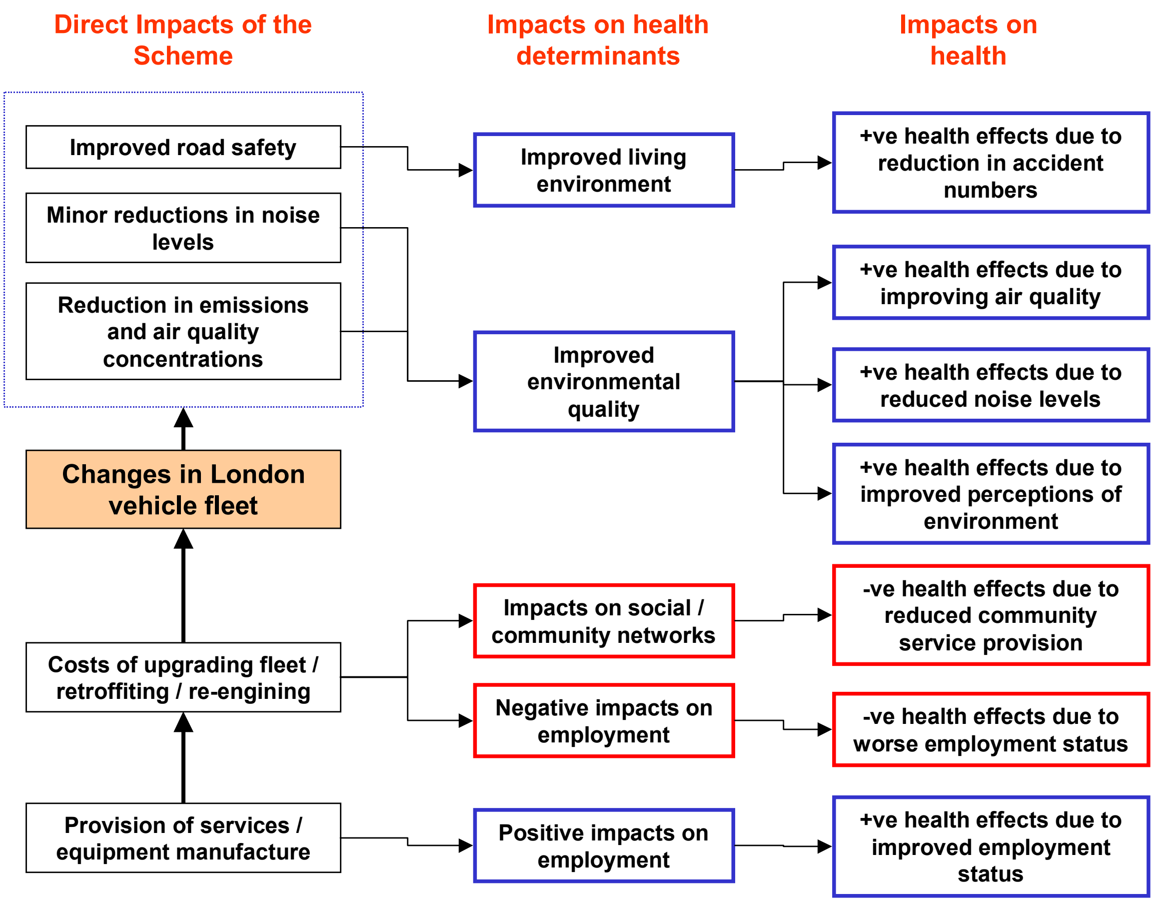
The scoping phase of this study provided a useful first assessment of the LEZ scheme proposal, and how it might impact on the different health determinants affecting the population's health. Some of the linkages identified between health and transport schemes are presented in Figure 4.1 (Watkiss et al. 2000).

Figure 4.1 Links between factors affecting health, and the effects of transport schemes



Focusing on the proposed LEZ, as described in section 2, the scoping phase identified the main health effects and health inter-linkages of the LEZ, illustrated in Figure 4.2 below. This was an important part of the scoping phase, and has provided a focus for the full appraisal and stakeholder engagement.

Figure 4.2 Anticipated health impacts associated with the possible implementation of the London Low Emission Zone



The left hand side of Figure 4.2 shows the direct impacts of the proposed LEZ, covering both socio-economic and environmental impacts. The potential impact on factors affecting health (determinants), and subsequent impacts on health result from these direct impacts of the scheme. From Figure 4.2, it appears that there may be a greater overall positive effect on health arising from the scheme (as suggested by the previous HIA (ERM 2006)). The appraisal phase of the HIA (described later in this section, and in Sections 5 of this HIA) investigates the significance of the effects on health, and helps prioritise these impacts for TfL.

4.2 LITERATURE REVIEW

4.2.1 Introduction

A literature review was undertaken to determine what evidence was available from published studies that would help in the estimation of the nature and magnitude of health impacts arising from implementation of the proposed LEZ. The full literature review can be found in Appendix 1. Through our understanding of the issues from the scoping phase of the study, and in reference to the previous HIA (ERM 2006), we focused on a number of specific issues for review:

Air pollution and health:

- Evidence linking traffic emissions to adverse health effects, the nature of any health effects specifically associated with traffic pollution and by inference the health improvements that would be expected following a reduction in pollution exposure;

- The effectiveness of measures (LEZ or other) to reduce air pollution and other environmental improvements giving rise to measurable improvements in health;

- Information about which groups are potentially most vulnerable to the adverse effects of air pollution (and therefore who would be the most likely to benefit if the LEZ was implemented).

Perception of environmental quality:

- The importance of perception in determining the influence of environment on health and the extent to which a perceived improvement in environmental quality might lead to health benefits.

Socio-economic and other effects:

- The relationship between changes in socio-economic and/or employment status and health in order to understand the potential impacts on health that might arise if the LEZ were to adversely affect some businesses;

- Effects of noise and, therefore, the likely effects of a reduction in noise exposure on health;

- The potential impacts of improved road safety in reducing traffic accidents and the groups most likely to benefit.

4.2.2 Air pollution and health

Specific role of traffic pollution in the relationship between air quality and health

The adverse health effects of exposure to air pollution have been extensively studied and well established exposure-response functions (more accurately concentration-response functions) are available for the calculation of the impacts of traffic pollution on life expectancy, respiratory and cardiovascular health, including emergency hospital admissions and GP consultations. A significant amount of activity in reviewing the evidence of health impacts and further developing quantification methodologies has occurred in the last three years, particularly through the European Commission's Clean Air for Europe (CAFE) programme and the UK Air Quality Strategy Review. The World Health Organization (WHO 2005) have also recently specifically reviewed the health effects of transport-related air pollution within the overall framework of the CAFE programme, updating an earlier review undertaken in 2000 (WHO 2000).

Studies have informed our understanding of the health impacts associated with air pollution, both for impacts of increased mortality risk, and increases in morbidity effects e.g. respiratory illnesses. Two important sets of studies undertaken in the US have demonstrated that long-term exposure to particulate matter is associated with an increased mortality risk (The American Cancer Society (Pope et al. 2002) and Harvard six cities studies (Laden et al. 2006)) and similar findings have also been reported from a recent European study. The American Cancer Society studies (Pope et al. 2002) have formed the basis of the concentration-response function used in the effects quantification for the proposed LEZ described below (for both Defra and CAFE approaches). Other studies in Europe (including studies in London), North America and elsewhere have demonstrated that exposure to airborne particles and possibly nitrogen dioxide is associated with an increased risk of emergency admission to hospital for respiratory or cardiovascular illness (e.g. Anderson et al 1997 and 2001).

Studies in London have reported relationships between air quality and GP consultations for respiratory illness (Hajat et al, 1999). Less well-established relationships linking exposure to air pollution to respiratory symptoms and mild illness that may lead individuals to modify their daily routine (restricted activity days) or cause an increase in their use of respiratory medicine also exist.

Most of these studies have been undertaken in panels of subjects, most often children, with or without pre-existing respiratory conditions, both in Europe and North America. Although the numbers of individuals experiencing increased respiratory symptoms as the result of air pollution are likely to be considerably greater than those admitted to hospital or seeking primary care, there is considerable uncertainty in the estimation of effects. This reflects the difficulties in defining the health endpoints of interest, in identifying a study population and gaining co-operation to undertake studies, and the very large number of different influences on respiratory health.

The concentration-response relationships that have been used in the quantification of the benefits likely to arise as a result of implementation of the proposed LEZ are those that have been used in regulatory impact analysis for the UK (Defra) Air Quality Strategy Review (IGCB 2006), based on the underlying work in the Department for Health's COMEAP (Committee on the Medical Effects of Air Pollutants) and also in the EC's CAFE programme and the resulting Impact Assessment of the Thematic Strategy on Air Pollution (CEC 2005; health methodology described in detail in Hurley et al. 2005).

Respiratory effects in children

There have been a large number of studies that have attempted to specifically link traffic emissions to adverse health effects. A large proportion of these studies have examined respiratory effects in children. This partly reflects a specific concern about the vulnerability of this group, but it may also reflect the relative ease with which it is possible to conduct studies in representative samples of school children as opposed to adults. Other studies have examined effects on birth outcome, cancer risk, and cardiovascular and respiratory health in adults.

The results of studies conducted in children suggest that there is a weak association between exposure to vehicle emissions as assessed through residential proximity to heavy traffic and respiratory symptoms. Most studies suggest an increase in risk of about 20-30% for children living near heavily trafficked roads compared with other children, although the results of some studies suggest a much greater relative risk; other studies have failed to detect an effect.

There is also evidence to support a possible association between exposure to traffic pollution and the prevalence of asthma, and limited evidence that suggests that exposure to traffic pollution may increase the likelihood of children becoming sensitised to a range of allergens that may give rise to respiratory symptoms. The results of a number of studies indicate that effects are most strongly associated with HGVs and that therefore the benefits of reducing emissions from heavy vehicles would be disproportionately greater than those arising from reducing traffic emissions more generally. There are limited data that suggest that respiratory effects arising from exposure to traffic pollution may be greatest in very young children and that exposure during very early childhood may have long term impacts on respiratory health. Adverse effects do not appear to be confined to those with asthma.

Respiratory effects in adults

A small number of studies have established that long term exposure to traffic pollution is associated with an increased risk of respiratory illness in adults, although it is not clear how adequately socio-economic factors have been accounted for in published studies. The increase in risk of long term respiratory illness associated with living in close proximity to a major road appears to be much less than two fold.

Other effects

A number of studies have demonstrated an association between exposure to traffic pollution and short term effects on cardiac function, whilst other studies have demonstrated longer term effects on life expectancy.

The results of a number of studies have suggested a link between exposure to road traffic and a small increased cancer risk in children whereas other studies have failed to demonstrate an association. Overall, although carcinogens are present in traffic emissions, there is little evidence that residential proximity to traffic is associated with a substantially increased cancer risk. Cancers have many causes and childhood cancers are particularly poorly understood. Although it seems unlikely that traffic pollution is associated with a substantially increased cancer risk in children, it is difficult to entirely discount an association with a slightly increased leukaemia risk.

A number of studies have found associations between air pollution and premature birth and/or low birth weight. A smaller number of studies have specifically examined pregnancy outcome in relation to exposure to traffic emissions. Overall, the results of published evidence would suggest that residential proximity to traffic is associated with a small increased risk of adverse effects on pregnancy outcome, although there are many other influences on foetal and maternal health during pregnancy.

In summary, there is a substantial quantity of evidence to link exposure to pollution to a range of adverse health effects such that the implementation of the LEZ would be expected to have a beneficial effect on health. The evidence is strongest, in terms of traffic pollution, for HGVs which supports the implementation of the LEZ for heavy vehicles, ahead of other vehicle types. There is a general consensus that fine particles are the most damaging component of air pollution and little evidence that the introduction of measures that would specifically target NO_2 rather than particles would have a substantial benefit. This supports the approach that TfL have taken with a focus on the reduction of particulate rather than NO_2 emissions.

<u>Effects of air quality improvements</u>

We have not identified any studies that have assessed the health impacts of other LEZ schemes. However, other studies on intervention measures do suggest that substantial improvements in air quality give rise to measurable improvements in life expectancy, respiratory and cardiovascular health and that reductions in air pollution are associated with an immediate beneficial effect on health. Studies of the impacts of banning coal sales in Dublin (which led to a 70% reduction in concentrations of PM) and of a sudden halving of HGV traffic at US-Canadian border crossing appear to demonstrate that air quality improvements are associated with a very rapid improvement in population health. The improvement in air quality associated with the proposed LEZ would, however, be an order of magnitude lower than that observed in these studies. This is because the reduction in emissions predicted to arise from the proposed LEZ is much smaller.

A study of the impacts of the opening of a bypass on a town in North Wales demonstrated that reduced exposure to traffic emissions was associated with a small improvement in respiratory health, against a relatively high background prevalence of respiratory symptoms. The proportionate change in respiratory health symptoms reporting was small relative to the proportionate change in concentrations of PM_{10}. Other studies have also demonstrated a reduced prevalence of respiratory symptoms in children following the implementation of measures to reduce emissions and improve air quality.

In an investigation of the effects of long-term exposure to $PM_{2.5}$ in six US cities, reduction in particle exposure between the early 1980s and the 1990s was associated with a decrease in mortality rate (Laden et al. 2006). The cities with the greatest reductions in $PM_{2.5}$ also showed the greatest fall in mortality rates. The reduction in risk was greatest for cardiovascular and respiratory disease and there was a much smaller reduction in lung cancer risk. The smaller effect for lung cancer was attributed to its longer latency and less reversibility than cardiovascular or respiratory disease.

In summary, studies undertaken elsewhere have confirmed that health benefits are observed following the implementation of measures targeted at improving air quality. Overall, the results of these studies suggest that implementation of the LEZ would be expected to confer an immediate and lasting benefit on respiratory and cardiovascular health, though its influence may be relatively small in comparison to other factors.

Groups susceptible to air pollution

The results of a number of studies suggest that the poor, the elderly, children and those with pre-existing illness may be most vulnerable to the adverse effects of air pollution. There is also growing evidence that deprivation is associated with an increased sensitivity to air pollution (in addition to any relationship between deprivation and increased exposure) e.g. because of poorer diet, lower health status higher unemployment, less access (or poorer access) to health care. For a given increment in air pollution the impact on health is greater for these groups than for the general population, and therefore these groups are most likely to benefit from reduced air pollution levels following introduction of a LEZ.

It is likely that some of the greatest improvements in air quality, from the introduction of a LEZ, would be experienced in deprived communities that currently have high (above average) levels of air pollution (e.g. communities close to busy roads). The predicted benefits for these communities may therefore be larger from an LEZ where larger decreases are experienced.

In conclusion, it is likely that the actual health benefits arising from the predicted improvement in air quality following implementation of the LEZ would be greater for vulnerable groups and could reduce health inequalities (i.e. it would have a positive effect in reducing existing inequalities).

4.2.3 Perceived environmental quality and health

There is growing evidence that people's health (especially in the context of wider well being) is influenced by their perception of their local environment. The implementation of a LEZ may bring a benefit as a result of the perceived improvement in air quality, over and above the predicted health benefits (cardio and vascular effects) from air quality improvements resulting from the LEZ. There is often a poor correlation between perceived and actual air quality and there is some evidence to link perceived poor air quality with respiratory symptoms and other subjective effects such as headache. Although the improvement in air quality arising from implementation of the LEZ is unlikely to be perceptible in sensory terms, the publicity surrounding its introduction and the expected benefits could lead to the perception that air quality has improved.

In addition to direct health benefits that may arise from people having a positive view of their local environment, there are a number of potential indirect benefits. A perception of good environmental quality might encourage participation in walking and cycling giving rise to improved health in those who participate (physical exercise has positive health outcomes in reducing coronary heart disease and in reducing other health impacts such as type 2 diabetes, obesity, hypertension, cancer, osteoporosis and even depression), though it is stressed that these activities tend to be more strongly influenced by traffic volume and speeds, which are not affected by a LEZ. It might also encourage parents to allow their children to venture outdoors to play or to walk/cycle to the activities they participate in, with direct health benefits from increased exercise and indirect benefits on well being arising from increased independence.

In summary, the literature evidence suggests that perception of improved environmental quality following the introduction of the LEZ could have a small beneficial effect on well being leading to slightly improved health status in some individuals. The perceived improvement in environmental quality might also encourage greater participation in walking and cycling giving rise to improved health in those who participate. It is difficult to predict the relative importance of this effect on health as there are few relevant published data. Provision of information on the air quality and health benefits of the LEZ to the general community may play an important role in giving rise to health improvements.

4.2.4 Socio-economic and other effects

<u>Effects of socio-economic changes on health</u>

Employment status has an important influence on health and well being. Loss of employment is associated with increased risks of mental and physical illness and re-entry into employment is associated with improved health. The health effects of changing jobs are less clear.

Studies of the influence of individual socio-economic status on health have given rise to mixed results with some studies showing that neighbourhood characteristics are more important than individual socio-economic status. There is limited evidence to suggest that weaker social networks in some deprived areas may contribute to adverse effects on well being. Deprivation is associated with increased risks of mental illness, cardiovascular and respiratory illness.

Changes in employment status arising as a result of implementation of the LEZ could have important consequences for the health of affected individuals. Any loss of employment arising as a result of business closures following the introduction of the LEZ could be associated with an increased risk of mental or physical illness in the newly unemployed.

Effects of noise exposure

High levels of exposure to noise are associated with annoyance (and associated adverse effects on mental well being), sleep disturbance, increased risks of cardiovascular illness and effects on children's learning and behaviour. The World Health Organisation (WHO 2000a) considered that transport noise was an underestimated cause of stress and illness and identified children, the hearing impaired, the elderly and those who are ill as being at particular risk. Children in school may be particularly vulnerable to noise, with some studies linking higher noise levels with decreased educational performance; therefore, there may be some benefits where schools are located immediately alongside busy roads. Noise also has detrimental effects on amenity (and wider well being).

There is general agreement that noise is a source of annoyance. There are, however, problems in interpreting the direct and indirect health impacts from noise and annoyance, because annoyance is related to the duration and the frequency components of sound and relies on subjective measures and the sensitivity or susceptibility of individuals. The evidence for effects of environmental noise on health are strongest for sleep disturbance, ischaemic heart disease and performance by school children – much of the other evidence in support of actual health effects is quite weak. The data on other possible health consequences, such as low birth-weight and psychiatric disorders, are inconclusive.

The impact of implementation of the LEZ on average noise exposure in London is expected to be very small. A small reduction in noise in the immediate vicinity of the most heavily trafficked routes from the LEZ would be likely to lead to a very small marginal amenity benefit (e.g. as a reduction in the noise of vehicles driving by, and of the perception of noise levels). While it might (in theory) also lead to a very small health benefit for local residents, given the low average levels of noise reduction from the LEZ, this seems unlikely.

Road traffic accidents – influences on risk of injury

The results of several studies have suggested that the risks of injury in a road traffic accident increase with increasing deprivation. Road traffic statistics also show that children are particularly at risk (as pedestrians) as a disproportionate number of children are killed or injured compared to the population as an average.

The LEZ has the potential to improve the potential safety of heavy goods vehicles, by encouraging modern vehicles, which tend to have greater safety features and are better maintained (this could potentially reduce the risk or the severity of accidents).

The levels of reduction in road traffic accidents from the LEZ is, however, likely to be very low, as it does not alter traffic volumes or speeds. Based on average statistics, it is possible that any benefits in reducing accidents might have a potentially greater benefit for children (and particularly for deprived children) in that these groups have a higher average risk of involvement in road traffic accidents, though in practice, it would seem most likely that the largest benefits would be in reducing risk to vehicle drivers.

One additional aspect (revealed through the stakeholder consultation, was the potentially wider benefits from LEZ compliance and monitoring in identifying illegal vehicles or drivers. However, it is not considered likely that the levels of changes in accidents from the LEZ would lead to wider perceptions about safety (e.g. in relation to issues of community severance) because the LEZ would not affect vehicle numbers or speeds.

4.3 STAKEHOLDER ENGAGEMENT

As part of the HIA process, it was important that the views of interested stakeholders were sought to help identify the different health impacts arising from the proposed scheme introduction, to prioritise the significance of such impacts, and to consider how positive impacts could be maximised and any negative impacts minimised.

Two stakeholder engagement meetings were held with a total of 12 participants. In addition, two individuals who were unable to attend either meeting provided comments by phone or email. The aim of the stakeholder meetings was threefold:

- To determine what positive and negative health effects resulting from the LEZ introduction were identified by stakeholders
- To understand the stakeholders' perception of the relative importance of these effects
- To discuss how stakeholders thought benefits could be maximised and any disbenefits minimised.

At each meeting, stakeholders were presented with background information about the proposed LEZ and the purpose of the HIA. They were then asked to individually identify the positive and negative impacts of most concern to their organisations. Each individual response was then discussed by the group; each group was subsequently asked to suggest how additional benefits would be accrued through implementation of the LEZ and disbenefits minimised.

The following organisations, listed alphabetically, provided input to the stakeholder engagement exercise via the meetings, by email or via telephone interviews:

- Age Concern England
- Asthma UK
- British Heart Foundation
- Camden Primary Care Trust
- Redbridge Primary Care Trust
- Community Transport Association
- Croydon Primary Care Trust
- CTC Working for Cycling
- Health Care Commission
- Health Protection Agency (representatives from both the Air Pollution Unit and the North East and North Central London Unit)
- Institution of Civil Engineers
- London Borough of Richmond Upon Thames
- St John Ambulance

It is important to stress that the comments summarised below are attributable to the stakeholders, and do not necessarily represent the views of TfL or the study team. They are useful because they help to highlight the concerns of some of the stakeholder groups, and provide further information with regard to what the positive / negative health effects might be, and how these might be enhanced / minimised.

4.3.1 Potential positive health benefits

The stakeholders identified the main benefits of the proposed LEZ as being:

- An improvement in respiratory and in cardiovascular health due to improved air quality;
- An improvement in mental well being arising from a perceived improvement in environmental quality;
- An increased willingness to participate in walking and cycling as a result of the perceived improvement in air quality and the potential improvement in physical fitness with benefits for cardiovascular and respiratory health;
- Other benefits to physical and mental well being related to an increased use of outdoor space, and a consequent increase in community cohesion arising from a perceived improvement in environmental quality.

Other potential benefits identified by stakeholders included:

- Health benefits arising from the speeding up of the introduction of new technologies such as hydrogen-powered vehicles giving rise to a greater reduction in emissions to air.
- Possible improvements in road safety due to the introduction of newer vehicles and the increased surveillance used to enforce the LEZ acting as a deterrent for reckless drivers or those driving untaxed or uninsured vehicles, reducing the number of such vehicles on the roads. A perceived improvement in road safety would help to encourage participation in walking and cycling and might also encourage parents to allow children greater freedom to participate in outdoor play.
- Health benefits arising elsewhere if nationwide organisations decide to update their national fleets in line with the LEZ, or to pre-empt other possible LEZ schemes in different parts of the country, leading to an overall reduction in emissions.
- Benefits that may arise in other cities that choose to follow the example set by London by creating their own LEZ.

It was felt that these benefits could be enhanced if initiatives to encourage the use of street space and participation in walking and cycling were co-ordinated with the implementation of the LEZ. A particular need to encourage participation in cycling in disadvantaged communities was identified. It was also felt that good publicity would be essential to create the perception of environmental improvement that might lead to changes in behaviour and associated health benefits. It was also suggested that stronger fiscal measures might be required to encourage businesses to meet the requirements of the LEZ rather than simply pay the daily charge, although this was not an issue of general concern to stakeholders. Several stakeholders queried whether the air quality impacts of the LEZ might be enhanced by an extension of its scope to include cars.

The general consensus among stakeholders was that the introduction of the LEZ should be beneficial to health and that the benefits could be maximised by integration of the introduction of the LEZ with other measures.

4.3.2 Potential negative health impacts

The main potential negative impacts of the proposed LEZ scheme identified by stakeholders included:

- The possible loss of services/amenities to disadvantaged groups e.g. the old or deprived groups, who rely on community transport services which may not be able to afford to comply with the LEZ regulations. The types of organisations that would be affected could include age concern, organisations catering for the disabled, social inclusion projects, and low-income group projects. These services provide not only access to health care but also access to facilities such as day centres, shops and community outings. Increased social isolation for those reliant on community transport could be expected to have negative mental health effects. There was a concern that the positive health impacts of reduced emissions may be directly counteracted by the negative effect of reduced mobility upon these groups.

- A closely related impact was identified by St John Ambulance who provide first aid cover for London events including sporting events, demonstrations, Royal events and Lord Mayor events. St John Ambulance have 250 vehicles in London and the cost of upgrading their non-compliant vehicles to meet the requirements of the LEZ would be likely to lead to the organisation being unable to continue to cover the range of events that they currently attend. This could have implications for health care provision at public events.

- Stakeholders from the healthcare sector identified another closely related impact in that public sector vehicles owned by local authorities or hospitals would be affected by the LEZ. If these organisations cannot afford to replace or retrofit any non-compliant vehicles with pollution abatement technology, services such as meals on wheels or mobile libraries could be reduced with adverse consequences for those dependent on these services. Unlike in the community/voluntary sector, where organisations may have to cut services altogether, in the public sector the most probable impact could be that services are reduced or cut.

- Stakeholders were also concerned about potential negative impacts on small businesses owning non-compliant vehicles (in particular heavier LGVs) affected by the LEZ. Economic constraints could mean that these businesses were unable to replace or upgrade their vehicle(s), and may in extreme cases be forced out of business. This could lead to job losses, and could have knock-on economic and social effects in already-deprived communities, where these small businesses are more likely to be found. This could be expected to have adverse effects on the health and well being of those directly affected. It may also have a more general adverse effect on wellbeing in the community as a whole if small retail businesses and other businesses serving local residents cease trading. No specific mitigation measures were identified.

Other potential adverse impacts that were judged to be of less concern were:

- Potential clutter arising from additional signage for the LEZ causing a reduction in perceived environmental quality and also creating an additional hazard for the visually impaired

- A potential increase in vehicle numbers as community transport organisations may react to the LEZ by increasing their reliance on cars (such as MPVs) rather than minibuses to deliver voluntary services

- An increase in the number of very large vehicles on the road if companies choose to replace several LGVs with fewer larger HGVs to cut costs. Larger vehicles reduce safety for cyclists and pedestrians and their presence on roads may deter walking and cycling.

- The implementation of the LEZ may result in the displacement of pollution outside of London by the following mechanisms: nationwide organisations relocating their non-compliant vehicles outside of London, and other organisations selling their non-compliant vehicles to organisations located outside London.

- Also, if the LEZ leads to vehicles being scrapped/retired from the road earlier than they otherwise would have been, this may lead to an increase in pollution if the life cycle environmental costs of producing and scrapping vehicles are taken into account.

It was considered by some stakeholders that some form of exemption, phased introduction or financial assistance should be provided to reduce the potential adverse impact of the LEZ on services provided for vulnerable people by both the voluntary and public sector.

4.3.3 Conclusions

Overall, stakeholders were of the opinion that the air quality benefits of the LEZ and the perceived improvement in environmental quality would be beneficial. The benefits could be maximised by integrating the introduction of the LEZ with other measures to encourage participation in walking and cycling, and to create a perception of improved environmental quality. The potential negative impacts of greatest concern was the impact on community transport and the potential for increased social isolation of vulnerable individuals including the elderly and disabled.

Some stakeholders felt that the potential negative impacts that could arise from the introduction of the LEZ could be appropriately managed by making modifications to the scheme such as providing exemptions for community transport, allowing a longer timescale for compliance or providing assistance with the cost of retrofitting pollution abatement technology to the vehicles. There was a concern that if the unintended consequences of the LEZ such as the potential impact on community transport were not properly managed, then the overall impact of the LEZ on health could be damaging rather than beneficial. There was a consensus that it should, however, be possible to manage these unintended consequences and that the LEZ should give rise to an overall benefit to health.

None of the stakeholders suggested a specific monitoring programme to gauge the actual health impacts resulting from the proposed LEZ.

4.4 COMMUNITY PROFILE

A community profile was compiled to get a better understanding of the socio-economic and health characteristics of people living in Greater London, which could be affected by the introduction of a LEZ. The purpose of the community profile, a common element of most HIAs, is to understand the location of types of communities in order to consider where health impacts would be most significant. The usefulness of an impact assessment is limited if it only indicates total impacts of a scheme without considering the variation across and between different areas.

In the context of this HIA, we were most interested in understanding the distribution of health impacts associated with improvements in air quality, as these are considered to be the most significant. To investigate this, we considered the following statistics:

- Air quality data, to identify where the highest concentration levels are found
- Population distribution across Greater London, to identify where population densities are highest
- The location of communities who are considered most vulnerable to the impacts of air quality due to their age or socio-economic profile
- Health statistics that illustrate the incidence of specific illnesses in a given area

In addition, we were also interested in the distribution of health impacts associated with possible changes in employment resulting from the introduction of the proposed London LEZ, and impacts on the provision of transport and related services to the wider community.

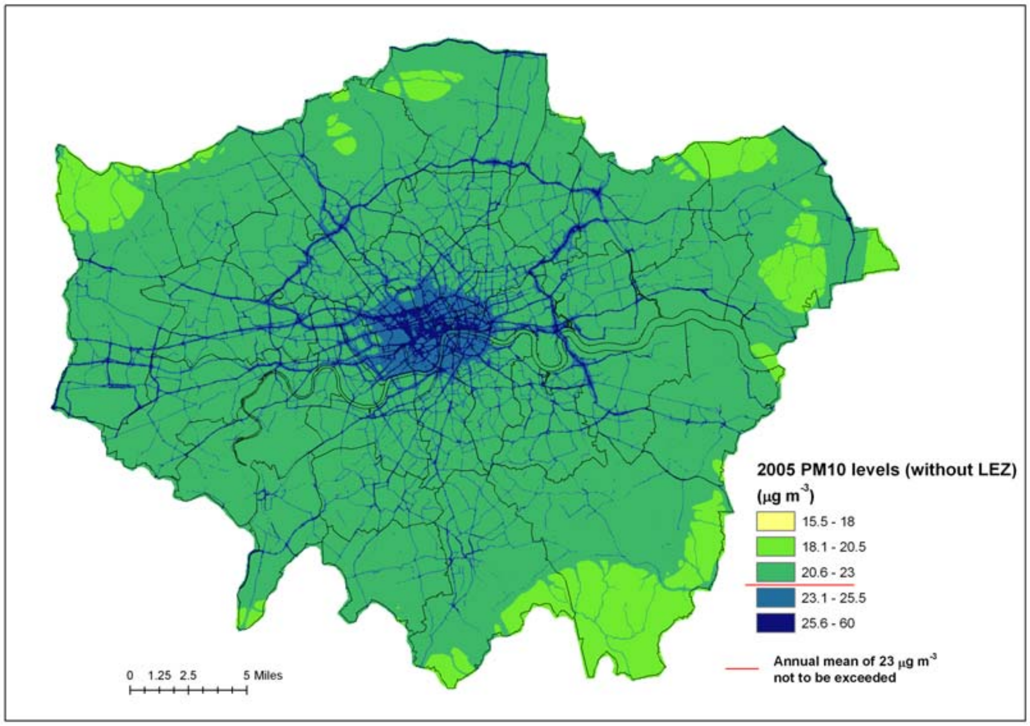
This section provides an overview of the baseline data that help develop the analysis of the distribution of health impacts, described in section 5.

4.4.1 Air quality and health

Air quality

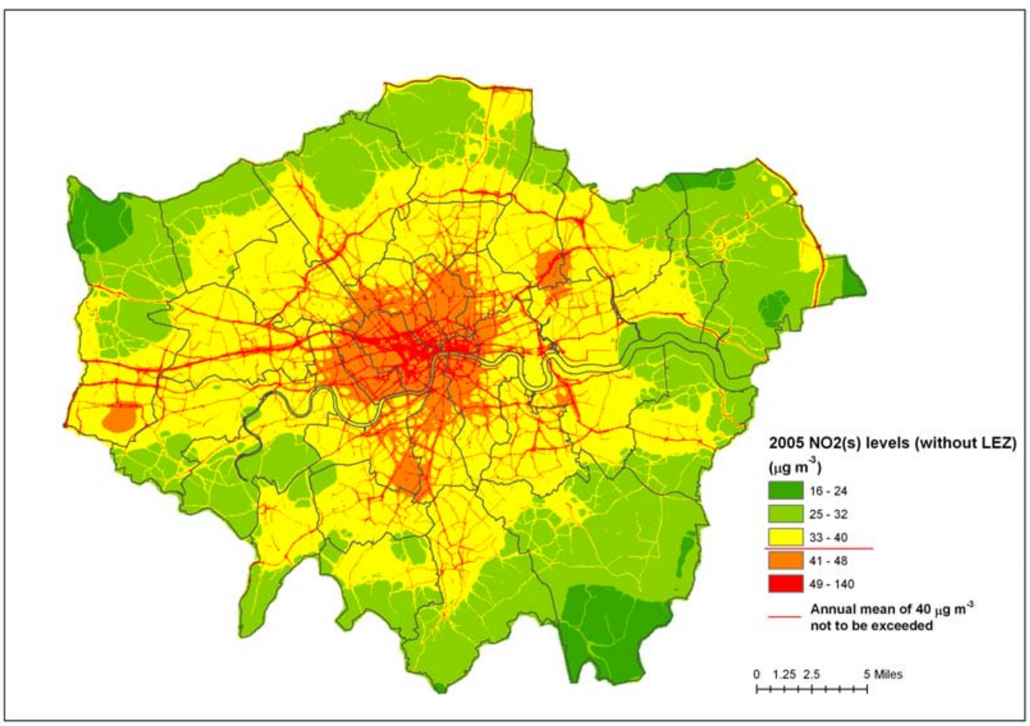
Air quality, as measured by concentrations of PM_{10} and NO_2, is significantly affected by the road transport emissions in Greater London. Modelled air quality concentrations of PM_{10} and NO_2 in 2005 are illustrated in Figure 4.3 and Figure 4.4. The highest concentrations are found primarily in Central London Boroughs, where road transport density is highest, and along the major roads, including the North Circular (A406) and M4.

Figure 4.3 PM_{10} concentrations across Greater London in 2005



Source: Concentration data provided by ERG, LEZ Phase 5 modelling (2006)

Figure 4.4 NO_2 concentrations across Greater London in 2005



Source: Concentration data provided by ERG, LEZ Phase 5 modelling (2006)

To illustrate the differences in air pollution levels in different boroughs, an analysis was undertaken to calculate the proportion of a borough population and the actual population in areas where the 2010 air quality targets are expected to be exceeded. The data are presented in Table 4.1. This provides an indicator of which boroughs currently experience the worst air quality (as measured by this indicator), and information though which assessment of which boroughs (in relative terms) would experience the most benefit from the proposed LEZ implementation can be used.

The boroughs that have the greatest proportion of the population in exceedence areas are primarily those in central London. The projected population exceeding the 2010 limit value for NO_2 of 40 $\mu g/m^3$ is estimated to be over 1.2 million in 2008. Westminster, Kensington and Chelsea, and City of London are projected to have 90% of their population in exceedence areas. These boroughs, plus Camden and Islington, account for over 40% of this projected population in exceedence areas across London.

The projected London population exposed in areas with PM_{10} concentrations greater than 23 $\mu g/m^3$ is smaller, at just under 0.5 million. The same areas account for the largest proportion of the projected population in exceedence areas. This is also the case for the indicator of areas where 10 days exceed a daily mean of 50$\mu g/m^3$ PM_{10} (on an annual basis).

These indicators are more useful than simply assessing the average levels of pollutant concentrations because they feature population numbers exposed to high pollutant concentration levels; this provides an indication of the potential distribution of health impacts, and which boroughs may realise most health benefits from the introduction of a LEZ.

Table 4.1 Proportion of borough populations in areas exceeding 2010 limit values in 2008 (prior to LEZ implementation)

Borough	Total population	% popn exc. 40 ug/m3 NO2	Population in NO2 exc. areas	% popn exc. 23 ug/m3 PM10	Population in PM10 exc. areas	% popn exc. 10 PM10 exc. days	Population in PM10 exc. days areas
Barking and Dagenham	163,932	1.2%	2,116	1.6%	2,705	0.9%	1,576
Barnet	314,506	5.5%	18,025	4.3%	13,925	2.8%	9,174
Bexley	218,316	1.5%	3,355	1.6%	3,652	0.9%	1,959
Brent	263,507	10.4%	28,610	4.4%	11,938	2.4%	6,646
Bromley	295,544	0.3%	829	0.5%	1,646	0.3%	790
Camden	198,038	53.5%	110,124	20.6%	42,512	10.8%	22,337
City of London	7,162	100.0%	7,448	49.8%	3,712	34.6%	2,581
Croydon	330,562	4.4%	15,028	3.1%	10,659	1.6%	5,595
Ealing	300,975	11.7%	36,500	6.9%	21,640	4.2%	13,207
Enfield	273,530	3.7%	10,654	4.2%	12,036	3.1%	8,957
Greenwich	214,412	6.8%	15,161	4.8%	10,794	3.1%	6,863
Hackney	202,832	23.3%	49,221	7.4%	15,622	3.9%	8,151
Hammersmith and Fulham	165,156	32.2%	55,372	10.5%	17,988	6.3%	10,824
Haringey	216,498	8.4%	18,909	4.1%	9,257	2.2%	4,984
Harrow	206,822	0.4%	911	0.8%	1,724	0.3%	540
Havering	224,243	0.5%	1,137	0.9%	2,124	0.5%	1,059
Hillingdon	243,065	3.3%	8,376	2.5%	6,199	1.4%	3,573
Hounslow	212,340	5.3%	11,746	5.6%	12,328	3.6%	7,997
Islington	175,792	50.7%	92,775	11.3%	20,700	6.1%	11,242
Kensington and Chelsea	158,902	89.9%	148,648	23.3%	38,490	15.7%	26,010
Kingston upon Thames	147,218	2.4%	3,696	3.6%	5,462	2.4%	3,665
Lambeth	266,143	30.7%	85,111	9.8%	27,115	5.7%	15,746
Lewisham	248,910	9.6%	24,740	5.0%	12,936	2.9%	7,500
Merton	187,924	6.5%	12,753	2.9%	5,707	1.7%	3,272
Newham	243,820	10.3%	26,197	3.8%	9,569	2.0%	5,086
Redbridge	238,666	4.3%	10,777	3.7%	9,074	2.1%	5,330
Richmond upon Thames	172,345	2.4%	4,329	3.5%	6,206	2.4%	4,352
Southwark	244,877	35.3%	89,936	12.6%	32,111	6.9%	17,508
Sutton	179,799	0.5%	947	1.4%	2,538	0.6%	1,146
Tower Hamlets	196,141	23.4%	47,668	12.1%	24,689	8.8%	17,859
Waltham Forest	218,278	20.6%	46,832	4.4%	9,963	2.7%	6,048
Wandsworth	260,393	25.2%	68,307	6.3%	17,107	3.8%	10,264
Westminster	181,276	93.4%	176,042	38.7%	72,939	20.9%	39,394
Totals	7,171,924		1,232,282		495,069		291,234

NB. Values highlighted for where percentage greater than 20% for NO_2, 10% for PM_{10}, and 5% for PM_{10} exceedence days. Estimates based on concentration data provided by ERG, LEZ Phase 5 modelling (2006)

Socio-economic profile and age

In addition to assessing the distribution of population and air quality across Greater London, we have also considered the profile of certain areas in terms of socio-economic characteristics (measured by levels of deprivation) and age profile. Deprived communities may be more vulnerable to health impacts associated with air quality due to location (i.e. they are in areas of higher pollution) or from confounding factors such as existing poor health, and therefore their distribution needs to be analysed. Similarly, different age groups may be more vulnerable to health impacts, and therefore it is important that age group distribution relative to pollution levels is considered. Health issues relating to vulnerable groups are discussed in the literature review in section 4.2 and Appendix 2.

Figure 4.5 shows differences in the socio-economic profile of communities across London, using an index of multiple deprivation compiled on behalf of ODPM (ODPM 2004). Decile 1 represents the most deprived communities whilst decile 10 represents the least deprived areas. The highest levels of deprivation are predominantly seen in central London, and immediately to the north (e.g. Hackney, Islington), east (e.g. Tower Hamlets), and south (e.g. Southwark, Lambeth and Lewisham) of the central area.

Figure 4.5 Deprivation levels (as measured by Index of multiple depreciation in 2004) by Super Output Area (lower level) for Greater London

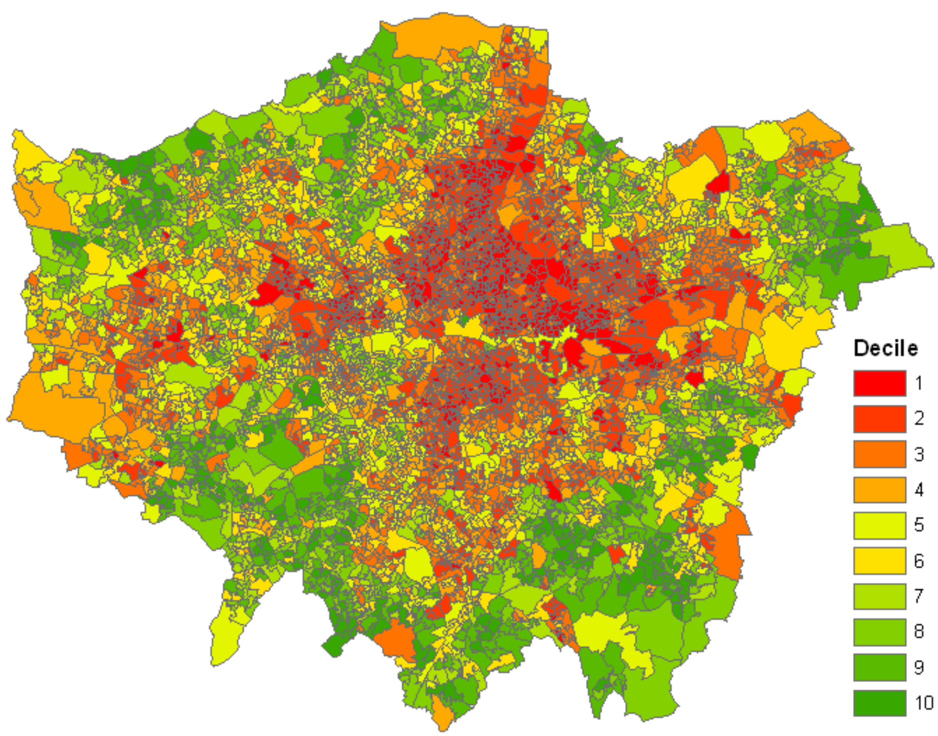
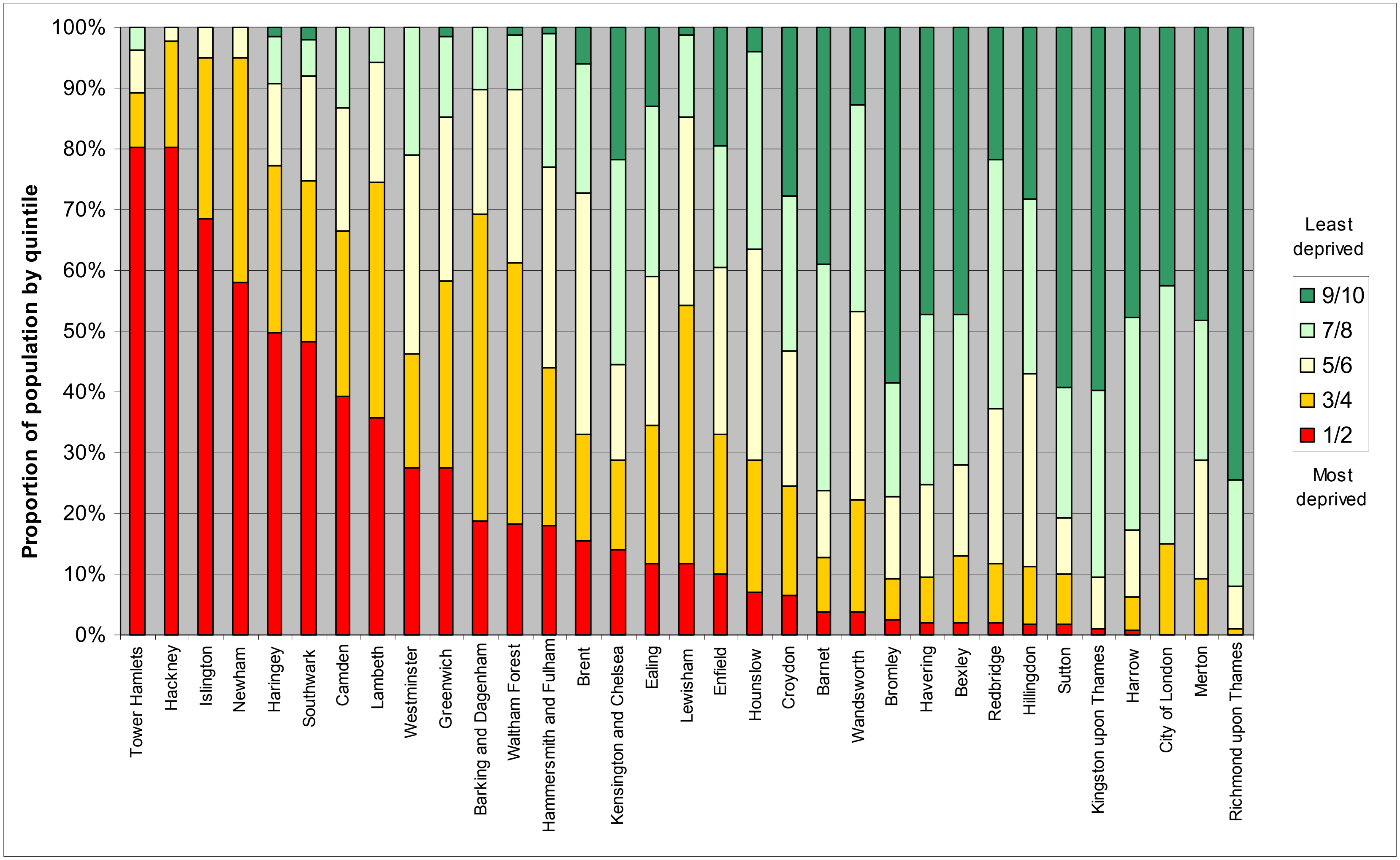


Figure 4.6 Socio-economic profile (as measured by levels of deprivation) across London boroughs



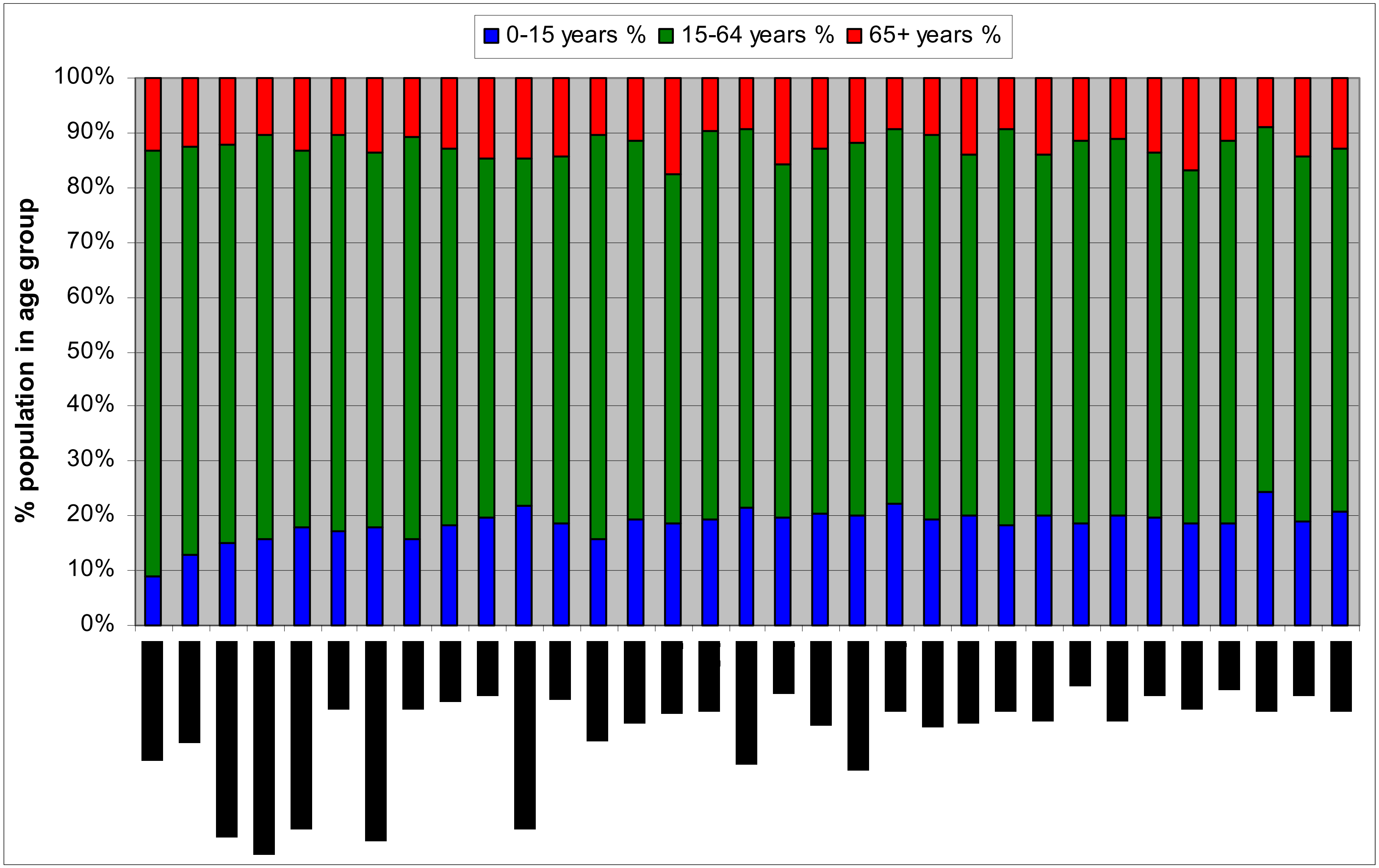
Source: ODPM (2004)

Figure 4.6 presents the data in the preceding map at the borough level. It shows relative levels of deprivation by quintile in each borough, with the *1/2* category being the most deprived, and the *9/10* category the least deprived. In general terms, it is the Boroughs to the north, south and east of central London which show the highest deprivation levels. The least deprived boroughs are those covering the outer London areas, with the notable exception of the City of London.

Vulnerability to health impacts may also be affected by the age of the population. Assessing the age profile across boroughs is important to identify differences, which could lead to variation in vulnerability of different populations. The age profile, showing the proportion of the population in each age group, is presented in Figure 4.7.

Limited variation can be seen across boroughs, and in isolation does not provide any insights into differences in vulnerability. In the air quality analysis (section 5.1), we use these data to compare with the pollutant concentration data to determine if any one age group experiences higher concentrations relative to other groups.

Figure 4.7 Percentage of population by age group by London Borough



Health statistics

In the same way that we see variation between communities with regards to the environmental quality they experience, differences in incidence of illness also exist. Such differences could have important implications for vulnerability to health effects associated with air pollution.

The baseline health status of Londoners is very heterogeneous. Male life expectancy in different boroughs ranges from 73.3 – 79.8 years. For comparison, the impacts of air pollution (from all sources) on life expectancy might typically equate to a shortening of life of about 2-3 months for the average Londoner. The Standardized Mortality Ratio (SMR) in London boroughs ranges from 67 in Kensington and Chelsea to 117 in Islington.

This variation, reflected in the data in Table 4.2, could have important implications for the prediction of health benefits arising from the LEZ as any change in health arising from changes in air quality is proportional to existing baseline conditions. For example, for a given reduction in particle exposure there is a predictable percentage change in risk of emergency hospital admission with the largest reduction number of admissions likely to arise in populations with the highest baseline admission rates.

The impact of the variable health baseline (e.g. differences in background rates of illness in different areas) could lead to a variation in the benefits arising from the LEZ with the benefit per unit reduction in pollution being greatest in areas that currently have the poorest health status. However, this may not be the case. The rationale that higher background rates of illnesses associated with air quality e.g. asthma rates, or respiratory hospital admissions would lead to increased impacts needs to be carefully considered due to issues of circularity. Higher background rates may be due to poor air quality and therefore may not actually reflect increased vulnerability (Pye 2006). As a result, in the health benefits modelling, the same average baseline rates are used across all London areas.

The status of health is important in assessing differences in vulnerability to air pollution, and therefore should be regarded as an important part of the community profile. However, due to the issues discussed, this variability is not reflected in the quantification methodologies.

Table 4.2 Selected health statistics for London

Area	SYLL – Asthma[1]	SYLL – Bronchitis[2]	Respiratory admissions[3]
England and Wales	2.8	1.5	
London	3.4	1.2	
City of London	0.0	0.0	326
Barking and Dagenham	3.4	2.4	1,190
Barnet	0.9	1.3	800
Bexley	1.7	2.1	1,116
Brent	6.2	0.3	887
Bromley	2.9	1.2	874
Camden	4.2	0.1	1,122
Croydon	5.5	1.9	891
Ealing	4.5	0.0	1,108
Enfield	3.3	0.0	896
Greenwich	2.2	0.6	1,174
Hackney	2.7	2.3	1,930
Hammersmith and Fulham	0.9	4.4	1,167
Haringey	4.5	0.5	1,050
Harrow	3.5	1.4	800
Havering	0.9	0.6	1,168
Hillingdon	2.4	3.3	672
Hounslow	6.0	0.1	1,188
Islington	4.8	2.0	1,266
Kensington and Chelsea	5.7	1.6	742
Kingston upon Thames	1.0	1.2	1,107
Lambeth	2.3	1.5	1,114
Lewisham	6.4	0.9	1,058
Merton	6.0	2.7	1,079
Newham	4.7	0.5	1,035
Redbridge	4.6	1.2	905
Richmond upon Thames	0.1	0.3	840
Southwark	2.3	0.5	1,140
Sutton	3.6	0.3	991
Tower Hamlets	3.0	1.6	1,314
Waltham Forest	1.4	0.2	1,007
Wandsworth	1.0	2.7	1,197
Westminster City of	5.9	1.7	1,086

[1] Mortality from asthma (ICD10 J45-J46), Average annual SYLL (Years of Life Lost) (per 10,000), 1999 and 2001 pooled, Compendium of Clinical and Health Indicators 2002 / Clinical and Health Outcomes Knowledge Base (nww.nchod.nhs.uk), DoH 2003

[2] Mortality from bronchitis and emphysema (ICD10 J40-J43), Average annual SYLL (Years of Life Lost) (per 10,000), 1999 and 2001 pooled, Compendium of Clinical and Health Indicators 2002 / Clinical and Health Outcomes Knowledge Base (nww.nchod.nhs.uk), DoH 2003

[3] Hospital admission rates for respiratory disease per 100,000 aged 1-19, 2003/04, Hospital Episode Statistics (HES)

4.4.2 Employment in different sectors

Employment effects resulting from LEZ implementation could lead to positive or negative impacts on health. The additional costs incurred by businesses through compliance with the proposed LEZ could result in job losses. On the other hand, the LEZ would speed up the replacement rates of vehicles, and generate an increased demand for sales of new vehicles. In addition, increased demand would be seen for vehicle retrofitting and the manufacture of abatement technologies used in retrofitting.

Distributional impacts can be considered in two ways – firstly, the differences in impacts between sectors, and within sectors e.g. size of business or type of business and secondly, the areas in which impacts might be greatest due to the location of sector employees or businesses.

SDG (2006) have undertaken an economic impact assessment of the LEZ to accompany the consultation on the LEZ Scheme Order, in which they have considered the type of vehicles and the sectors that are most likely use these vehicles. The distributional impacts are considered in further detail in section 5.2.

4.4.3 Provision of community services

There may be impacts on the community access to services where vehicles that provided access via transportation or a specific service are lost / downsized due to increased costs, or become unaffordable to certain groups. Such services might include the following:

- Minibuses used by community groups, including ethnic, voluntary, youth, and disabled groups
- Transport services provided by the public sector e.g. non-emergency ambulance vehicles or social service vehicles
- Bus services for schools within London or public bus services that may operate on the London boundary
- Vehicles used to deliver community services e.g. Meals on Wheels, St. Johns Ambulance
- Public sector service provision e.g. mobile libraries

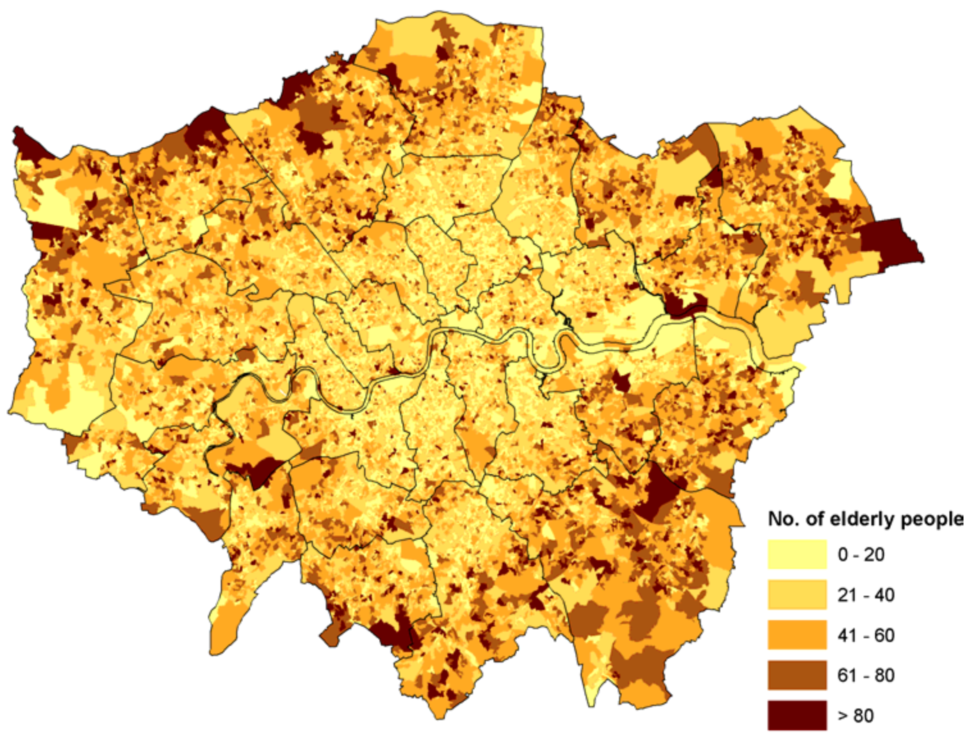
Much of the voluntary provision of transport services in the community is through Community Transport Associations (CTAs). The 25 CTAs in London serve one million people. For example in Brent, four vehicles funded by the Local Authority provide 16,000-17,000 trips per quarter, with average trip length being 4-5 miles (point to point, not including distance from vehicle depot to pickup point). In other words, they are used by a significant proportion of the population.

Determining which communities are the most reliant on such services is problematic because of a lack of data on the service provision and its distribution, and because there is likely to be significant variation of provision of such services within communities as well as between communities.

If there are significant impacts on community services, it is likely to affect the groups that use these services the most, namely the elderly and deprived communities. Spatial statistics can provide some understanding concerning where such locations may be.

The distribution of elderly, who are less mobile and may rely on community services to a greater extent than other population groups, is shown in Figure 4.8. The density of elderly people, as might be expected, it greatest in areas outside of the central area, in the outer London boroughs.

Figure 4.8 Distribution of elderly population



Source: Census 2001 Output Area statistics (21,400 areas) (KS02 Age Structure), Office for National Statistics

Deprived communities may rely more on community transport and support services, and therefore could be vulnerable to greater impacts if such services are affected. The distribution of deprivation is provided earlier in this section on ‘Air quality and health’.

5 Assessment of the LEZ proposal

This section of the HIA brings all elements of the appraisal process together. Information from the literature review, stakeholder engagement, and community profile are used to provide a full assessment of the potential effects of the LEZ scheme on the health of the population. The following health impact areas are considered in this section:

- *Air quality improvements*, resulting from the reduction in vehicle-based emissions
- *Socio-economic impacts on health*, particularly associated with changes to employment and provision of community services
- *Improvements in road safety* due to changes to vehicle stock
- Health impacts associated with changing *perceptions of environmental quality*
- Other environmental improvements, including *reductions in noise*

5.1 AIR QUALITY IMPROVEMENTS

5.1.1 How does air quality affect health?

Studies of air pollution episodes (such as the London smog episodes of the 1950s) have shown that very high levels of ambient air pollution are associated with strong increases in **adverse health effects**. More recent studies also reveal smaller increases in adverse health effects at the current levels of ambient air pollution typically present in urban areas. The health effects associated with short-term (acute) exposure include premature mortality (deaths brought forward), respiratory and cardio-vascular hospital admissions, exacerbation of asthma and other respiratory symptoms.

The evidence for these effects is strongest for particles (usually reported in terms of fine particles (PM_{10})[3]) and for ozone (O_3). For these pollutants the relationships are widely accepted as causal. Recent studies also strongly suggest that long-term (chronic) exposure to particles may also damage health and that these effects (measured through changes in life expectancy) may be substantially greater than the effects of acute exposure described above. A detailed review of the literature on the health effects can be found in section 4.2 and Appendix 2.

Due to the health concerns associated with many pollutants, UK and European legislation has been introduced to improve air quality. The UK Government (the Air Quality Strategy for England, Wales and Northern Ireland, 2000, and its Addendum, 2003) and the EU (Air Quality Framework Directive) have introduced air quality targets for *concentrations* of pollutants, referred to as 'objectives' in the UK Air

[3] Note that PM_{10} includes the $PM_{2.5}$ fraction. According to the National Atmospheric Emissions Inventory (NAEI), $PM_{2.5}$ accounts for approximately 90% of PM_{10} from vehicle exhaust emissions (www.naei.org.uk).

Quality Strategy (UK AQS) and 'limit values' in the EU Directive, that are to be achieved by given dates. The UK AQS provides the key mechanism for implementing the EU Directive. The LEZ is considered to be an important mechanism for helping London progress towards these targets.

The most challenging target for NO_2 is the annual mean concentration, set at 40 $\mu g/m^3$, which was due to be met by the end of 2005 (UK Air Quality Strategy). The same target (40 $\mu g/m^3$) is also set by the EU legislation, but with the date for achievement of 2010 (i.e. the EU legislation is less stringent). In contrast, the 1-hour mean short-term target for NO_2 will be met across all of London, even without an LEZ. For PM_{10}, the first target was an annual mean concentration of 40 $\mu g/m^3$ to be achieved by January 2005 under both the UK and EU legislation. This standard was provisionally tightened to 23 $\mu g/m^3$ in 2010 for London under the UK AQS Addendum (it is tightened to 20 $\mu g/m^3$ for the rest of the UK) and as an indicative EU Limit Value at 20 $\mu g/m^3$.

5.1.2 How are air quality health effects measured?

The usual approach taken for the detailed quantification of reducing the benefits of air pollution emissions through to health impacts is often referred to as the 'impact pathway approach' - a logical progression from emission, through dispersion and exposure to quantification of impacts (with the potential option of continuing through to valuation).

Impacts under any scenario are calculated using the following general relationship:

$$impact = pollution \times stock\ at\ risk \times response\ function$$

Where:

pollution is ambient pollution concentration:
stock at risk is population, or sub-group of population (e.g. age specific)
Exposure *response function* is the concentration response functions identified in the underlying epidemiological studies.

The main issue centres on which concentration functions to use. The approach used for quantifying health effects here is based primarily on the new Defra methodology, as developed for the Defra UK Air Quality Strategy Review (AQSR), and published by the IGCB (the Inter-Department Group on Costs and Benefits) in April this year (IGCB 2006). This methodology is based on the underlying work and recommendations of the UK's Department for Health's COMEAP group (Committee on the Medical Effects of Air Pollutants). The approach draws on the work and recommendations on the relationships (functions) between air pollution and health for quantification of air pollution and health in the UK.

The functions recommend by COMEAP are mostly based on the results of time-series studies. These are relationships between daily levels of pollutants and the risk of adverse health effects, on the same or subsequent days, adjusting for weather and other factors (effects of acute exposure, also known as 'acute health effects'). They provide relationships for Respiratory Hospital Admissions (RHA): and Cardio-Vascular Hospital Admissions (CHA) and represent a stay in hospital as a result of high air pollution of 4 to 14 days on average. Later work by COMEAP also added additional relationships based on cohort studies, (longer-term, possibly lifetime exposure and health 'chronic' effects) notably in looking at the change in life expectancy, known as 'chronic mortality'. The functions allow quantification of 'Years of Life Lost'/'Chronic Morality'. This measures the impact of long-term and life-time exposure to air pollution, i.e. the fall in life expectancy that results from long term exposure to air pollution.

Acute functions have been provided by COMEAP for particles, sulphur dioxide and ozone for deaths brought forward and respiratory hospital admissions. Chronic functions are provided for particles. The functions for PM have been applied to UK average baseline data for mortality and RHA/CHA (rather than using London specific data).

COMEAP did not provide functions of NO_2 in view of the difficulties and doubts about the relationships between exposure to NO_2 and effects on health[4], though a possible relationship for the effects of the pollutant on respiratory hospital admissions was included. The lack of UK studies and uncertainties about the independent effect of carbon monoxide (CO) led COMEAP not to estimate the effects of this pollutant.

Consistent with this, the analysis has assessed the effects of PM on health, but has not quantified any direct effects of NOx (or NO_2). However, NOx emissions also have effects on health through the formation of secondary pollutants, including secondary particulates. The analysis has considered the effects of NOx as a secondary pollutant (precursor) for secondary PM (though note for the latter, the health benefits will largely occur outside London as this is a regional scale pollutant).

For chronic mortality, a central estimate of 6% per 10 μgm^{-3} $PM_{2.5}$ is now used, consistent with the AQSR and a recent COMEAP (2006) interim statement on mortality and long-term exposure to air pollutants, particularly relating to ambient particles.[5] Note that consistent with the IGCB analysis, the function is applied directly to marginal changes in transport PM_{10}. In relation to the lag period, i.e. the period between exposure and impact, a lag of both 0 and 40 years has been used.

An alternative quantification approach has been used by the European Commission in the recent analysis (Hurley et al, 2005) of the Clean Air for Europe (CAFE) programme, and reported in the Thematic Strategy on Air Pollution. This approach does have significant differences to that used in the UK by Government, in that it covers a much wider range of health impacts (morbidity).

We highlight that the emission / air quality analysis does not cover the effects of ozone. This is an important secondary pollutant, and the evidence for the health

[4] Note that the UK Air Quality Strategy identifies that at relatively high concentrations, NO_2 causes inflammation of the airways. There is evidence to show that long-term exposure to NO_2 may affect lung functions and that exposure to NO_2 enhances the response to allergens in sensitised individuals.

[5] On balance, the Committee recommended using a coefficient of 6% per $10 \mu g.m^{-3}$ $PM_{2.5}$ from the largest most extensively analysed cohort study (Pope et al, 2002). 'Interim Statement on the Quantification of the Effects of Air Pollutants on Heath in the UK', *Committee on the Medical Effects of Air Pollution*, Department of Health (2006). Available at http://www.advisorybodies.doh.gov.uk/comeap/pdfs/interimlongtermeffects2006.pdf

effects of ozone are strong. Potential consideration of this pollutant might be considered in subsequent analysis.

The analysis of health impacts has assessed changes from both primary particulates (as PM_{10}) and secondary particulates (as PM_{10}) from NO_X emissions. The approach here has used two alternative methods for quantification of health impacts. The health impacts from PM_{10} quantified under the two methods is summarised below.

Defra (IGCB/COMEAP	EC (CAFE)
Chronic mortality (years of life lost)	Chronic mortality (years of life lost)*
	Infant mortality
Respiratory hospital admissions	Respiratory Hospital Admissions
Cardio-vascular hospital admissions	Cardiac Hospital Admissions
	Chronic Bronchitis (adults)
	Lower respiratory symptom (children)
	Lower respiratory symptom (LRS) adults
	Respiratory medication use (children)
	Respiratory medication use (adults)
	Restricted Activity Days (adults)

* Note also expressed in an alternative metric, as premature deaths

The Defra approach also includes a number of sensitivity analyses, including (acute) deaths brought forward from PM_{10} and respiratory hospital admissions from NO_2. The full list of functions used is not reproduced here – but can be found in the underlying Defra IGCB (IGCB 2006), and EC CAFE cost-benefit analysis health assessment methodologies (Hurley et al. 2005).

The starting point for the impact pathway analysis is the spatially disaggregated analysis of emissions (sourced from the London Atmospheric Emission Inventory),[6] and the estimation of air quality concentrations in London. This analysis has been provided by ERG as part of the study. The methodology is not repeated here but can be found in modelling methodology report (ERG 2006). The data were then gridded using Geographical Information Systems (GIS) software.

Population data were provided by the GLA for Greater London (covering all London Boroughs) at an output area resolution. Output areas were linked to the grid used for the pollution data. A population value was derived for each grid cell, based on an area-weighted approach. Population values were imported into the analysis database. This database also holds factors for disaggregating the population values into different age groups, based on the associated output area profile.

To do this, the pollution model outputs from ERG were combined with stock at risk data from the GLA for population within the GIS to provide relevant receptor (populated) weighted concentrations for the scenarios. The data were combined, in turn, with concentration-response functions to estimate impacts.

[6] LAEI, Greater London Assembly, http://www.london.gov.uk/mayor/environment/air_quality/research/emissions-inventory.jsp

5.1.3 How might the proposed LEZ affect air quality and the health of the population?

In section 2.3, the changes to the vehicle fleet profile and subsequent reductions in emissions as a result of the LEZ implementation are shown. Emission reductions lead to decreases in modelled pollutant concentrations, and provide the basis for assessment of the health impacts.

The impact of the LEZ on air quality concentrations has been modelled in three different years, at stages in the scheme when significant changes occur. The modelling years are shown below.

- **2008**: HGVs, buses and coaches - Euro III for PM only
- **2010**: HGVs, buses and coaches - Euro III for PM only; Heavy LGVs and Minibuses - Euro III for PM only – or an alternative using a 10 year rolling average
- **2012**: HGVs, buses and coaches - Euro IV for PM only; Heavy LGVs and Minibuses - Euro III for PM only

The study interpolated linearly between years to provide a full time profile from 2008 to 2015. A further analysis was made assuming pre-compliance, i.e. with linear interpolation from the announcement of the potential scheme in 2005 through to implementation in 2008.

Figure 5.1 shows the modelled reductions in 2012 for PM_{10} and NO_2 after possible introduction of the scheme. The largest reductions are in central London, where traffic flow density is very high, and on some of the main roads outside central London.

Quantifiable health effects

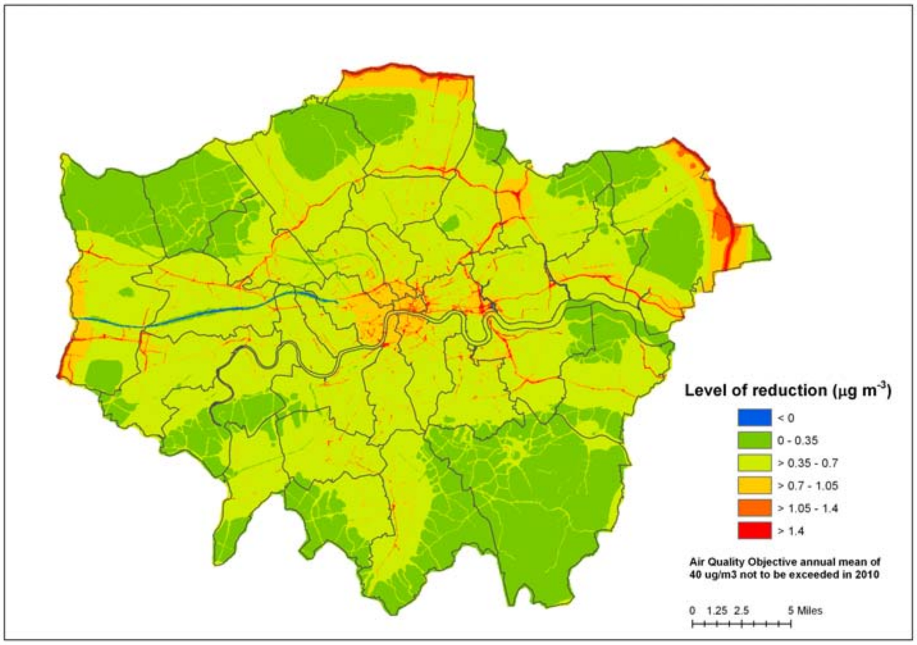
The health impact assessment method first uses the new Defra methodology, consistent with the UK Air Quality Strategy Review (Defra, 2006) and summarises benefits that occur in the period 2008 to 2015 for the proposed scheme.

Note the Defra analysis has two alternative assumptions on chronic mortality (the changes in life expectancy from air pollution, expressed as 'years of life lost') and the lag period (the time period between exposure and impact). These are 'no lag', and a '40 year lag'. Most recent evidence indicates that most effects happen in the first few years of exposure (i.e. towards 'no lag'). Due to the complex way that the underlying analysis using life tables work, the assumption of a 40 year lag phase actually leads to slightly higher health effects in terms of years of life gained.[7]

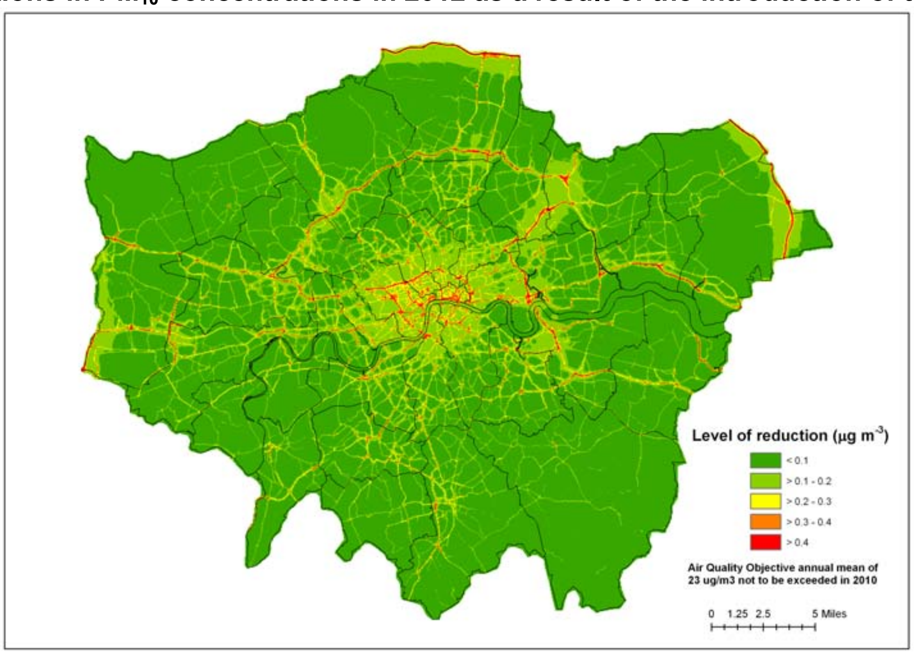
[7] When converted to monetary values (as shown in the following section later), the effect of discounting means that the monetary benefits under the 'no lag' phase are much higher.

Figure 5.1 Reductions in concentrations of PM_{10} and NO_2 after the possible introduction of the LEZ in 2012

Reductions in NO_2 concentrations in 2012 as a result of the introduction of the LEZ



Reductions in PM_{10} concentrations in 2012 as a result of the introduction of the LEZ



Source: Concentration data provided by ERG, LEZ Phase 5 modelling (2006)

Two additional sensitivity runs have also been considered.

- The first is for deaths brought forward from primary PM. This impact is no longer included in the main results (consistent with recent Defra methodology update), as this would potentially lead to double counting, as these 'deaths' are captured in the life expectancy (years of life) estimates.
- The second is an analysis of potential respiratory hospital admissions from NO_2 as recommended as a sensitivity analysis in the Defra methodology.

Table 5.1 Heath benefits from Primary PM_{10} improvements in Greater London area – Defra Methodology, 2008 to 2015. Detailed GIS analysis method.

Health effects	Scheme impact
Life Expectancy – Years of Life Gain – 40 yr lag	2,950
Life Expectancy – Years of Life Gain – no lag	2,715
Respiratory hospital admissions avoided	22.9
Cardiovascular hospital admissions avoided	23.0
Sensitivity on PM	
Deaths Brought Forward avoided	21.7
Sensitivity on NO_2	
Respiratory Hospital admissions avoided	*96.5*

The study also runs an alternative approach using the Defra unit pollution values, as recommended for use in Appendix 3 of the IGCB report on the Air Quality Strategy Review (Defra 2006). These are based on the netcen source receptor model, and detailed work undertaken in the AQSR. The unit pollution values are based on relationships of the exposure per tonne of emissions from transport in different types of location in the UK. They include three areas in London (CCS, inner and outer London).

There are two advantages of using these unit values. First, they capture the total effects of PM pollution more adequately than the GIS approach (because they capture the total health effects of PM emissions reductions and the longer distance transport of PM). Second, the pollution data analysis they are based on match more closely with the air quality monitoring data sites used in the underlying epidemiological models and therefore with the concentration-response functions (i.e. ambient background concentrations). There is a potential issue that the detailed GIS analysis above includes elements of roadside exposure because of the high resolution used, such that the model output is not really a reflection of ambient background (in theory this should bias the GIS based model output upwards).

The total health benefits up to and including the M25 are shown below. Figure 5.1 shows the benefits associated with a reduction in primary PM_{10}.

Table 5.2 Heath benefits from the LEZ - Primary PM_{10} improvements for all of London up to and including the M25 – Defra Methodology, 2008 to 2015. Unit Pollution Cost Approach

Health effects	Scheme impact
Life Expectancy – Years of Life Gain – 40 yr lag*	4,036
Life Expectancy – Years of Life Gain – no lag	3,713
Respiratory hospital admissions avoided	31.4
Cardiovascular hospital admissions avoided	31.4
Sensitivity on PM	
Deaths Brought Forward avoided	*29.7*
Sensitivity on NO2 (Greater London only)	
Respiratory Hospital admissions avoided	*96.5*

* Note the use of a lag leads to a higher number of YOLL calculated.

There are also health benefits from reductions in NOx emissions in reducing secondary PM_{10}. These health effects are additive to the direct PM benefits above and are important as they capture the benefits of LEZ NOx reductions (as no direct NO_2 effects are included). Note secondary pollutants form over time, and so arise at distance from the original emission source. The health benefits therefore include health benefits inside and outside London (indeed, given the nature of secondary pollution, a large proportion of benefits will occur outside London).

Table 5.3 Heath benefits from LEZ - Secondary PM_{10} improvements from NOx reductions for all of London up to and including the M25 – Defra Methodology, 2008 to 2015. Unit Pollution Cost Approach

Health effects	Scheme impact
Life Expectancy – Years of Life Gain – 40 yr lag*	929
Life Expectancy – Years of Life Gain – no lag	1010
Respiratory hospital admissions avoided	7.8
Cardiovascular hospital admissions avoided	7.9
Sensitivity on PM	
Deaths Brought Forward avoided	*7.4*

The above benefits can be added together to give the total health benefits, as shown in Table 5.4.

Table 5.4 Total Heath benefits from LEZ – Primary PM_{10} + Secondary PM_{10} improvements from NOx reductions - for all of London up to and including the M25 – Defra Methodology, 2008 to 2015. Unit Pollution Cost Approach

Health effects	Scheme impact
Life Expectancy – Years of Life Gain – 40 yr lag*	4,965
Life Expectancy – Years of Life Gain – no lag	4,723
Respiratory hospital admissions avoided	39.2
Cardiovascular hospital admissions avoided	39.3
Sensitivity on PM	
Deaths Brought Forward avoided	*37.1*

* Note the use of a lag leads to a higher number of YOLL calculated. Estimates include GL and area up to and including M25, and includes total health effects (inside and outside London) from reduction in primary PM and secondary particulate pollution from reduction in NOx emissions up to and including M25.

The effect of pre-compliance, i.e. from vehicle operators starting to switch to newer vehicles prior to LEZ implementation (i.e. changing fleet purchase or retrofit strategy) because of the LEZ, increases these benefits above. The total benefits with pre-compliance increase as shown in Table 5.5.

Table 5.5 Heath benefits from LEZ – Primary PM_{10} + Secondary PM_{10} improvements from NOx reductions - for all of London up to and including the M25 – Defra Methodology, 2006 to 2015. With Pre-Compliance. Unit Pollution Cost Approach

Health effects	Scheme impact
Life Expectancy – Years of Life Gain – 40 yr lag*	5,450
Life Expectancy – Years of Life Gain – no lag	5,188
Respiratory hospital admissions avoided	43.0
Cardiovascular hospital admissions avoided	43.1
Sensitivity on PM	
Deaths Brought Forward avoided	*40.8*

* Note the use of a lag leads to a higher number of YOLL calculated. Estimates include GL and area up to and including M25, and includes total health effects (inside and outside London) from reduction in primary PM and secondary particulate pollution from reduction in NOx emissions up to and including M25.

The analysis also uses the EC CAFE CBA health impact assessment approach, as this captures a wider range of potential health effects. The results from primary PM_{10} improvements for the Greater London area (only) with pre-compliance, are shown in Table 5.6. The EC methodology uses the detailed GIS-based methodology. Due to the unavailability of secondary PM_{10} concentration data, the benefits are only those associated with improvements in primary PM_{10}. Additionally, these benefits only include those in the Greater London area, and exclude the area between the Greater London boundary and M25.

Table 5.6 Heath benefits from Primary PM_{10} improvements in Greater London area – EC CAFE Methodology, 2006 to 2015. With Pre-Compliance. Detailed GIS analysis.

Health effects	Units	Scheme impacts
Cardiac Hospital Admissions	Admissions	24.9
Chronic Bronchitis (adults)	Cases	103.0
*Chronic mortality***	Premature deaths	209.3
Chronic mortality **	Years of life lost	2428.3
Infant mortality	Premature deaths	0.4
Lower respiratory symptom (children)	Cases	181202.3
Lower respiratory symptom (LRS) adults	Cases	132028.3
Respiratory Hospital Admissions	Admissions	40.4
Respiratory medication use (children)	Cases	17699.7
Respiratory medication use (adults)	Cases	12776.9
Restricted Activity Days (adults)	Days	230577.7

** Two alternative approaches are presented for chronic mortality – one similar to the Defra approach for years of life lost, the other expressing this in terms of premature deaths. The two sets are alternative ways of expressing the same effect (and are not additive).

Outer London benefits

As well as the benefits in London, a London LEZ is also likely to have air quality benefits outside London. A London LEZ would have an impact at a national level, because such a large number of vehicles operate in London. It is estimated that some 30-40% of the national lorry fleet, and perhaps 50% of the national coach fleet, operate in London during the course of each year.

The vehicles that are upgraded (retro-fitted, re-engined, or replaced) to comply with the London LEZ would therefore lead to emissions reductions and air quality benefits outside London, as these vehicles drive around the rest of the country over the year.

These benefits are estimated to be potentially very substantial, because of the proportion of the fleet affected, and because the relative distance (vehicle km) driven by most of these vehicles in London is likely to be low compared to the distance travelled each year nationally. This reflects the nature of HGV haulage and passenger transport by coach.

It is estimated that the numbers of vehicles that operate in London each year are around 60,000 articulated lorries, 100,000 rigid lorries, 10,000 coaches, and 330,000 large diesel vans.

Data from the operator surveys, undertaken as part of the analysis of the proposed scheme, indicate that a large proportion of the non-compliant vehicles in this fleet would be either upgraded, fitted with abatement equipment or replaced. The change in the fleet towards cleaner vehicles would therefore also lead to health benefits outside London, as these vehicles drive outside the capital over the course of a year. However, it is possible that around one quarter of operators would move their fleets around, to switch cleaner vehicles to London, and switch more polluting non-compliant vehicles to outside London routes. These redeployment effects would offset some of the benefits of the London LEZ outside London, and have been taken into account in the outside London analysis.

It is highlighted that the outside London benefits are potentially very large, because most vehicles only undertake a small proportion of their annual mileage in London, for example most artics and coaches will primarily be driving around the road network outside London due to the nature of their use. Data from the benefits study (Watkiss and Pye 2006c), using London vehicle km data combined with the vehicle numbers entering London, estimates that on average a rigid lorry or coach operating in London will only drive around 25% of its annual km in London (up to and including the M25) – and the average artic around half this value. Therefore most of the annual km will be outside London[8].

Underlying work in the health valuation analysis has quantified the health benefits outside London from a London LEZ (but only in monetary terms, not as physically quantified health benefits). As shown in the following section, the analysis shows that the health benefits outside London are of a similar order of magnitude to the direct health benefits in London.

Monetised health benefits

Health benefits have also been presented in monetary terms, reflecting the economic benefits of a reduction in health impacts. This valuation stage is generally done from the perspective of 'willingness to pay' (WTP). Some elements of the valuation of health impacts can also be quantified from 'market' data (e.g. the cost of medicines and care), though other elements such as willingness to pay to avoid being ill in the first place are clearly not quantifiable from such sources. Where impacts arise in the future it is necessary to discount monetised values (but not impacts).

For valuation of the health impacts estimated using the Defra methodology, the IGCB (2006) has produced recommendations on valuation endpoints for a range of health endpoints, including mortality (see Table 5.7). These recommendations have drawn upon recent research in the area, particularly the Defra-led study by Chilton et al (2004) which aimed to identify the willingness to pay to reduce the health impacts associated with air pollution, using a survey-style contingent valuation approach. To value chronic mortality, the analysis uses the concept of the value of a life year (VOLY). This updates earlier recommendations from EAHEAP.

[8] Note the health benefits are adjusted outside London to take into account the location of emissions and the likely population exposure (i.e. reduced down to reflect a large proportion of motorway driving).

Table 5.7 Summary of IGCB Recommendations on Health Valuation.

Health Effect	Description	Valuation – (2004 prices) Central Value
Acute Mortality (sensitivity)	Number of years of life lost due to air pollution (life years) – assuming 2-6 months loss of life expectancy for every death brought forward.	£15,000
Chronic Mortality	Number of years of life lost due to air pollution (life years) - Life-expectancy losses assumed to be in normal health.	£29,000
Respiratory Hospital Admissions	Case of a hospital admission - of average duration 8 days.	£1,900 – £9,100
Cardiovascular Hospital Admissions	Case of a hospital admission - of average duration 9 days.	£2,000 – £9,200

The values includes resource costs (e.g. NHS costs), opportunity costs (lost productivity) and dis-utility[9]. These agreed values have been used to monetise the health impacts. For chronic mortality, the analysis with life tables extends over time. In subsequent years, the values have been uplifted by 2%. This reflects the assumption that willingness to pay will rise in line with economic growth. The impacts are then discounted using the discount rate scheme recommended in the Green Book. The values used here are based on a form that is consistent with the annual pollution pulse as described in the IGCB update.

Table 5.8 Benefits (NPV £M) from Primary PM_{10} improvements and NOx reductions – Defra Methodology, 2008 to 2015. Unit Pollution Cost Approach.

Area	Scenario	Direct PM on health	NOx on health (secondary PM)	Total
Greater London*	Low (40 year lag)	49.2	8.6	57.8
	High (no lag)	71.8	12.5	84.2
	Average	60.5	10.5	71.0
London up to and including the M25**	Low (40 year lag)	58.4	14.6	73.0
	High (no lag)	85.2	21.3	106.4
	Average	71.8	17.9	89.7

[9] Note COMEAP, in the quantification report, presents the functions for respiratory hospital admissions as 'brought forward and additional', recognising that some or all of these cases would have occurred in the absence of the additional pollution. As is usual in most HIA work, we have assumed that hospital admissions attributable to air pollution are additional to those that would have occurred anyway, and not simply the bringing forward of admissions that would otherwise still have occurred, but only later. In practice, there is likely to be a mixture of both, but the underlying time series studies are strictly uninformative about the balance between them. We highlight that this assumption does not have a significant impact on the overall economic benefits (because the effects of RHAs are so low compared to the overall values).

* Note excludes health effects from outside GLA boundary ('external'). Note includes total health effects (inside and outside London) from reduction in secondary particulate pollution from reduction in NOx emissions within the GL boundary.
** Note includes total health effects (inside and outside London) from reduction in secondary particulate pollution from reduction in NOx emissions up to and including M25.

Table 5.9 Benefits (NPV £M) from Primary PM_{10} improvements and NOx reductions – Defra Methodology, 2006 to 2015. Unit Pollution Cost Approach. With pre-compliance.

Area	Scenario	Direct PM on health	NOx on health (secondary PM)	Total
London up to and including the M25**	Low (40 year lag)	64.3	16.4	80.7
	High (no lag)	93.8	23.9	117.6
	Average	79.1	20.1	99.2

Using the Defra quantification methodology for the proposed scheme, the estimated health benefits over the life of the scheme are approximately between £80m and £120m with a central estimate of £100m. This includes the benefits up to and including the M25, and those associated with pre-compliance (but not outside London benefits).

The CAFE valuation approach uses values for a life year lost (VOLY) from the DG Research NewExt study (2004) of Euro 52,000 to 12,000 (2000 prices) for chronic mortality. For reasons described in Hurley et al (2005), the CAFE approach also quantified mortality hazards based on the cohort studies in terms of 'attributable deaths' and valued using a Value for a Statistical Life (again from NewExt of Euro 980,000 to 2,000,000). This means that the CAFE approach generates four alternative values for mortality. For the analysis presented here, we have used an average of these four values. Other health endpoint values are reported in Hurley et al. (2005)

Table 5.10 Benefits (NPV £M) from Primary PM_{10} improvements and NOx reductions – EC Methodology, 2008 to 2015.

Area	Scenario	Direct PM on health	NOx on health (secondary PM)	Total
Greater London*	Low (40 year lag)	102.4	15.3	117.7
	High (no lag)	262.7	40.7	303.4
	Average	174.6	26.6	201.2
London up to and including the M25**	Low (40 year lag)	107.9	26.1	134.0
	High (no lag)	279.0	69.4	348.4
	Average	184.9	45.3	230.2

* Note excludes health effects from outside GLA boundary ('external'). Note includes total health effects (inside and outside London) from reduction in secondary particulate pollution from reduction in NOx emissions within the GL boundary.
** Note includes total health effects (inside and outside London) from reduction in secondary particulate pollution from reduction in NOx emissions up to and including M25.

Table 5.11 Benefits (NPV £M) from Primary PM_{10} improvements and NOx reductions – EC Methodology, 2006 to 2015. With pre-compliance.

Area	Scenario	Direct PM on health	NOx on health (secondary PM)	Total
London up to and including the M25**	Low (40 year lag)	119.8	29.7	149.4
	High (no lag)	309.8	78.7	388.5
	Average	205.2	51.4	256.6

Using the EC (CAFE) quantification methodology for the proposed scheme, the estimated health benefits over the life of the scheme are approximately between £150m and £390m with a central estimate of £260m. This includes the benefits up to and including the M25, and those associated with pre-compliance (but not outside London benefits).

Table 5.12 Summary of discounted monetised health benefits for both approaches used for health benefits quantification / valuation. London benefits include those for area up to M25, and include pre-compliance effects

Monetary health benefits (NPV £M)	UK (Defra) approach	EC (CAFE) approach
Primary (direct) Health Benefits	60 – 100 (80)	120 – 310 (210)
Secondary (indirect) Health Benefits	20 –20 (20)	30 – 80 (50)
Total London Benefits	**80 – 120 (100)**	**150 – 390 (260)**
Outside London Benefits	80 – 120 (100)	90 – 250 (160)
Total Benefits	**160 – 240 (200)**	**240 – 640 (420)**

Note above monetised benefits have been rounded to the nearest £10 million. Mean estimates are bracketed.

Table 5.12 provides a summary of the monetised health benefits. The range of values for the Defra method reflects differences in the health quantification, specifically for chronic mortality, and whether a lag is assumed between exposure and impact[10].

The range of values for the EC CAFE methodology reflect differences in the quantification and valuation of chronic mortality. The approach uses two alternatives approaches for quantification (estimating impacts in terms of either premature deaths or life years lost). It also uses a range of values for the valuation of each of these (for the Value of a Statistical Life – and the Value of a Life Year Lost) based around whether a mean or median value is used from the underlying NewExt valuation study that has been used. This leads to four alternative values – the numbers above take the low and high, plus an average from these.

[10] This makes a difference for valuation, as in the case where a lag is assumed, health benefits occur in the future and are therefore discounted.

The EC method gives rise to higher costs than the Defra method. There are a number of reasons for this.

- The EC method includes a wider range of health impacts, so quantifies (and values) more health endpoints.
- It does not assume a lag for chronic mortality (so health benefits are not discounted).
- The alternative method for chronic mortality – quantification of premature deaths - leads to higher values than the years of life lost approach.
- The valuation for years of life lost are slightly higher than the Defra study, due to the choice of different primary valuation studies (the Defra study uses a UK specific study).
- There is a slightly higher weighting given to NO_X in the EC approach, due to different source-receptor relationships, and the fact that the EC approach includes trans-boundary effects (i.e. including those health benefits that occur outside the UK).

The benefits outside of London, using either quantification approach, are estimated to significantly increase the overall benefits of the proposed scheme

<u>Non-quantifiable effects</u>

As well as the effects on PM, and NOx (and secondary pollution), there are also a number of other potential benefits. These include additional potential impacts from PM improvements not quantified, and the potential health benefits from reductions in other pollutants.

For the first of these, there are potential additional effects on morbidity from chronic (long-term) exposure to PM. On additional pollutants, the LEZ will also lead to reductions in primary emissions of:

- Carbon monoxide (CO)
- Volatile Organic Compounds (VOCs)
- Benzene and potentially Polycyclic Aromatic Hydrocarbons (PAHs)

The effects of CO on health are well known but previous studies (e.g. the Air Quality Evaluation (Watkiss et al, 2004)) have shown that health impacts from transport activity are many times (orders of magnitude) lower than for PM_{10} above. The same study found a similar finding for benzene and PAHs.

The one final area is on ozone; ozone (O_3) is a secondary pollutant formed in atmospheric chemical reactions between hydrocarbons (or VOCs) and oxides of nitrogen (NOx) in the presence of sunlight. It is a major pollutant of concern and is known to have serious impacts on human health, as well as effects on crops and some natural ecosystems. COMEAP (2006) recommends quantification of both deaths brought forward, and respiratory hospital admissions from ozone. However, the current study has not undertaken ozone modelling to see the effect of the LEZ in relation to health. Such an analysis is complex (see box), but is potentially relevant.

LEZ and the effects on ozone

Ozone (O_3) is a trans-boundary pollutant. Elevated concentrations of ozone over the UK are generated when slow-moving or stagnant high pressure (anticyclonic) weather systems (occurring in the spring or summer) bring in photochemically reacting air masses from mainland Europe. The formation and transport of ozone can occur over hundreds of kilometres, with concentrations at a given location influenced by the history of the air mass over a period of up to several days. Ozone formation is extremely complex and non-linear. There are also local and regional scale issues (within London, outside London at a regional scale, and trans-boundary) that complicate analysis.

In general, reductions of volatile organic compounds (VOC) emissions almost always reduce ozone – at both a local and regional scale. Note however, that the level of reduction is rather variable in magnitude. There will be VOC emission reductions from a London LEZ, which potentially would reduce ozone concentrations. However, the impact of changes in NO_x emissions (the other major ozone precursor) from a LEZ is much more difficult. Where NO_x is concerned, a decrease in NO_x emissions does not always lead to a reduction in ozone concentrations at the local or even the regional scale.

A release of NOx within an urban area may well cause an immediate decrease in ozone levels near the source. This is because of the titration reaction, $NO + O_3 \longrightarrow NO_2 + O_2$. Far downwind, in rural areas, the NOx release can cause increased ozone in most parts of Europe, with the exception of those rural areas still heavily influenced by anthropogenic NOx sources. In the context of the LEZ, the NOx emission reductions from the LEZ is could lead to a small increase in ozone concentrations in London, but would probably reduce ozone at the regional scale (i.e. outside London, across the UK).

5.1.4 What is the distribution of health impacts associated with air quality?

Due to significant variation across geographical areas, primarily as a result of different emission levels from road transport sources, understanding of the distribution of predicted health impacts from the LEZ is important. This section considers what the distribution in impacts might be, to provide an understanding of where benefits are most significant.

Pollution levels across London and the impact of the LEZ

The distribution of health impacts across Greater London has been determined through an analysis showing the proportion of a Borough population in areas where proposed 2010 air quality targets are exceeded. The benefit from possible LEZ implementation is measured by calculating the proportion of the people in exceedence areas prior to LEZ implementation who are not in exceedence areas post implementation. A summary of the results for Greater London is shown in Table 5.13.

Table 5.13 Reduction in population in areas where concentrations exceed limit values due to possible implementation of LEZ (under different analysis years)

Reduction in population exceeding 40 ug/m3 NO2			
Year	**Scheme description**	**Population reduction**	**Population reduction (%)**
2008	HGVs, buses and coaches: Euro III for PM only	101,150	8.2%
2010	HGVs, buses and coaches: Euro III for PM only; Heavy LGVs and Minibuses: Euro III for PM only	41,132	7.4%
2012	HGVs, buses and coaches: Euro IV for PM only; Heavy LGVs and Minibuses: Euro III for PM only	116,841	24.8%

Reduction in population exceeding 23 ug/m3 PM10			
Year	**Scheme description**	**Population reduction**	**Population reduction (%)**
2008	HGVs, buses and coaches: Euro III for PM only	31,237	6.3%
2010	HGVs, buses and coaches: Euro III for PM only; Heavy LGVs and Minibuses: Euro III for PM only	12,387	7.8%
2012	HGVs, buses and coaches: Euro IV for PM only; Heavy LGVs and Minibuses: Euro III for PM only	17,028	17.8%

Reduction in population or area exceeding 10 days above 50 ug/m3 PM10			
Year	**Scheme description**	**Population reduction**	**Population reduction (%)**
2008	HGVs, buses and coaches: Euro III for PM only	18,529	6.4%
2010	HGVs, buses and coaches: Euro III for PM only; Heavy LGVs and Minibuses: Euro III for PM only	7,692	7.6%
2012	HGVs, buses and coaches: Euro IV for PM only; Heavy LGVs and Minibuses: Euro III for PM only	8,333	16.1%

The spatial variation in the population of areas where concentrations are exceeding the objectives across Greater London can be assessed through analysis of the detailed concentration data used in this analysis. The results are presented at a borough level in Table 5.14.

In section 4.4 (community profile), the boroughs with the largest populations in exceedence areas were identified. This analysis explores the impact of the proposed LEZ on these exceedence populations, in terms of the percentage reduction of such populations in three of the years when the LEZ is proposed to be in operation. The full data tables for 2008, 2010 and 2012 can be found in Appendix 3. Care needs to be taken in the interpretation of these data where some very high percentage reductions are associated with small exceedence populations.

For NO_2 exceedence populations, it is the outer London boroughs with smaller exceedence populations that would experience the greatest relative benefit from the introduction of the LEZ. However, in absolute terms, it is the central London boroughs of Lambeth, Camden, Southwark and Islington that would experience the most significant reductions. Westminster and the City of London would experience smaller reductions due to the fact that even after the LEZ is introduced, concentration levels are still very high due to the very high baseline values. In later years of the LEZ scheme, the levels of reduction would differ depending on the baseline concentrations values without the introduction of the Scheme in that given year (see Appendix 3 for further information on later years).

In the PM_{10} analysis, the relative benefits again appear to be in the outer London boroughs, again largely due to the small baseline populations in exceedence areas. The highest absolute reductions again occur in the same boroughs as seen in the NO_2 analysis; the exception is Westminster, which shows the highest absolute reduction. The PM exceedence day analysis shows a more mixed set of results, probably as this pollution metric is more a function of the heavily trafficked roads passing through different Boroughs.

Table 5.14 Proportion of Borough population in exceedence areas (pre-LEZ), and reduction in population in exceedence areas post possible LEZ implementation in 2008

Borough	Annual mean NO2 > 40 ug/m3			Annual mean PM10 > 23 ug/m3			No. of days > 50 ug/m3 daily mean PM10		
	% popn exc. 40 ug/m3	Popn exc. 40 ug/m3	% reduction in exc. popn	% popn exc. 23 ug/m3	Popn exc. 23 ug/m3	% reduction in exc. popn	% popn exc. 10 days	Popn exc. 10 days	% reduction in exc. popn
Barking and Dagenham	1.2%	2,116	18.7%	1.6%	2,705	10.8%	0.9%	1,576	4.9%
Barnet	5.5%	18,025	10.2%	4.3%	13,925	5.1%	2.8%	9,174	5.0%
Bexley	1.5%	3,355	10.5%	1.6%	3,652	7.7%	0.9%	1,959	15.3%
Brent	10.4%	28,610	10.7%	4.4%	11,938	8.7%	2.4%	6,646	10.4%
Bromley	0.3%	829	17.4%	0.5%	1,646	3.7%	0.3%	790	11.6%
Camden	53.5%	110,124	7.3%	20.6%	42,512	5.4%	10.8%	22,337	3.3%
City of London	100.0%	7,448	0.0%	49.8%	3,712	4.0%	34.6%	2,581	10.5%
Croydon	4.4%	15,028	10.1%	3.1%	10,659	9.7%	1.6%	5,595	13.8%
Ealing	11.7%	36,500	7.8%	6.9%	21,640	4.8%	4.2%	13,207	7.5%
Enfield	3.7%	10,654	10.0%	4.2%	12,036	6.6%	3.1%	8,957	2.6%
Greenwich	6.8%	15,161	10.3%	4.8%	10,794	5.9%	3.1%	6,863	7.3%
Hackney	23.3%	49,221	11.6%	7.4%	15,622	9.7%	3.9%	8,151	12.1%
Hammersmith and Fulham	32.2%	55,372	8.7%	10.5%	17,988	6.5%	6.3%	10,824	7.1%
Haringey	8.4%	18,909	11.5%	4.1%	9,257	8.3%	2.2%	4,984	9.8%
Harrow	0.4%	911	19.0%	0.8%	1,724	12.3%	0.3%	540	13.2%
Havering	0.5%	1,137	12.5%	0.9%	2,124	6.6%	0.5%	1,059	4.3%
Hillingdon	3.3%	8,376	8.9%	2.5%	6,199	5.9%	1.4%	3,573	6.3%
Hounslow	5.3%	11,746	10.8%	5.6%	12,328	5.4%	3.6%	7,997	7.7%
Islington	50.7%	92,775	9.5%	11.3%	20,700	7.0%	6.1%	11,242	5.2%
Kensington and Chelsea	89.9%	148,648	4.9%	23.3%	38,490	3.7%	15.7%	26,010	2.6%
Kingston upon Thames	2.4%	3,696	5.8%	3.6%	5,462	6.8%	2.4%	3,665	6.2%
Lambeth	30.7%	85,111	12.1%	9.8%	27,115	6.7%	5.7%	15,746	7.6%
Lewisham	9.6%	24,740	10.1%	5.0%	12,936	9.3%	2.9%	7,500	11.6%
Merton	6.5%	12,753	13.5%	2.9%	5,707	10.6%	1.7%	3,272	4.0%
Newham	10.3%	26,197	12.2%	3.8%	9,569	11.4%	2.0%	5,086	3.7%
Redbridge	4.3%	10,777	10.6%	3.7%	9,074	4.1%	2.1%	5,330	5.0%
Richmond upon Thames	2.4%	4,329	9.1%	3.5%	6,206	7.1%	2.4%	4,352	5.4%
Southwark	35.3%	89,936	9.0%	12.6%	32,111	6.0%	6.9%	17,508	4.2%
Sutton	0.5%	947	31.5%	1.4%	2,538	12.7%	0.6%	1,146	13.2%
Tower Hamlets	23.4%	47,668	12.3%	12.1%	24,689	5.1%	8.8%	17,859	5.7%
Waltham Forest	20.6%	46,832	8.4%	4.4%	9,963	6.0%	2.7%	6,048	9.1%
Wandsworth	25.2%	68,307	11.1%	6.3%	17,107	5.9%	3.8%	10,264	8.3%
Westminster	93.4%	176,042	2.2%	38.7%	72,939	5.7%	20.9%	39,394	6.4%

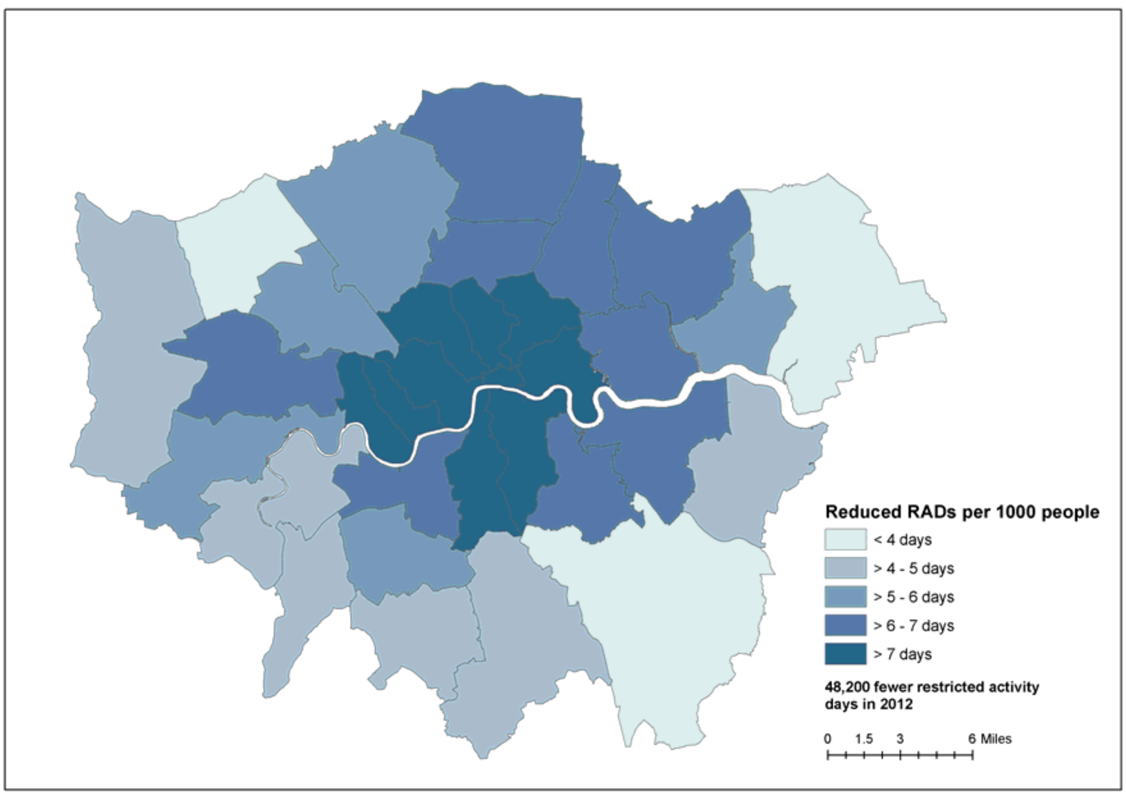
Source: Estimates based on concentration data provided by ERG, LEZ Phase 5 modelling (2006)

Reduction in health impacts across boroughs

The health benefits modelling calculates the health impacts at a 60m resolution across Greater London. This enables us to estimate the actual distribution of health impacts; the methods used to derive these health benefit numbers were described in detail earlier in this section. In this section we present the relative improvements by borough after possible LEZ implementation for the health end-point restricted activity days (RADs) calculated using the EC quantification methodology. We only present the data for one health end point as this should be broadly representative of the distribution of the other health impacts.

Restricted activity days refers to restrictions on individuals' ability to complete every day activities through ill health caused by poor air quality. In Figure 5.2, the cumulative instances of these curtailed activities are presented as the days lost per thousand people in each London borough. They are illustrative, using the EC approach to quantification, of which boroughs will see the most health benefits (normalized to borough population) due to air quality improvements resulting from LEZ implementation. The total numbers of restricted activity days prevented across London if the LEZ were implemented is estimated at some 48,200 days in 2012, from a number of 8.85 million before the introduction of the LEZ. This equates to a 0.54% reduction.

Figure 5.2 Reduction in restricted activity days per 1000 people by borough in 2012



It is the central London boroughs, and those immediately to the north, east and south that gain greatest health benefit. This would be expected as such areas have the highest modelled concentrations before the possible implementation of the LEZ; therefore, the impact of the LEZ is greatest in these areas. The above data are presented graphically in Appendix 3. This analysis uses the analysis year of 2012, a single year of the proposed LEZ. However, the results, in relative terms between boroughs, in other years would be similar. It is also broadly representative of the relative improvements between boroughs associated with other health impacts, quantified through both estimation approaches.

Air quality experienced by different socio-economic communities

There is an established association between deprivation and ill health giving rise to lower life expectancies and greater morbidity in deprived areas. This includes risks of cardiovascular and serious respiratory disease. There is increasing evidence that there is a greater proportionate increase in risk associated with a given increment in air pollution in deprived groups than in socially more advantaged groups. These issues are discussed in more detail in the literature review – see section 4.2 and Appendix 2.

Given that the most deprived communities may be more vulnerable to air quality health impacts than less deprived communities, it is important that they are considered as a specific group in the community. In addition, there is a body of literature (Walker et al. 2003; Pye et al. 2006; Fairburn et al. 2005) suggesting that the most deprived communities also experience higher than average concentrations. In summary, the most deprived communities may not only be more vulnerable than other groups to health impacts associated with air quality but may experience higher concentrations than other less deprived communities.

To explore the issue of air quality concentrations experienced by different socio-economic groups, a distributional analysis was undertaken to assess average PM_{10} concentrations across different deprivation deciles.[11]

In each assessment year, the *without LEZ* baseline and *with LEZ* scenario were assessed, and compared to estimate the change in average concentration. LEZ scenarios exist for 2008, 2010, 2012 and 2015 – we have used 2008 as the case study here. The other year scenarios show similar results.

[11] A decile includes (approximately) 10% of London's population, as ranked by levels of deprivation, with the decile 1 being the most deprived and decile 10 being the least deprived.

Figure 5.3 Average concentrations of PM_{10} in 2008 prior to possible LEZ implementation

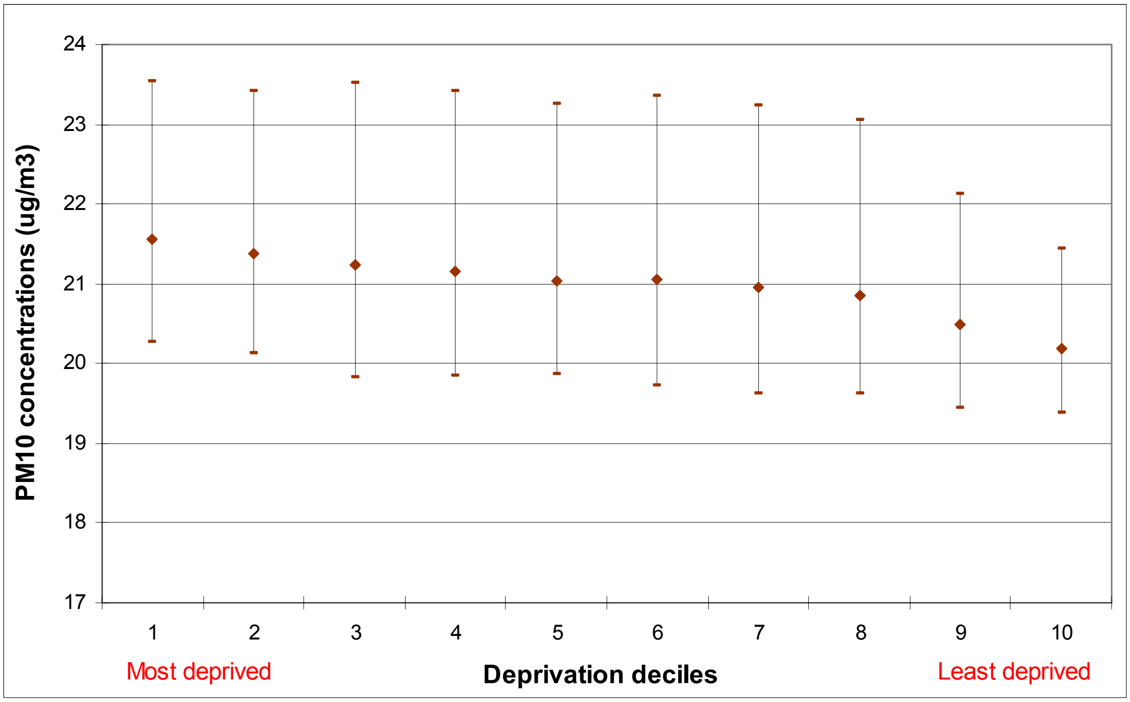
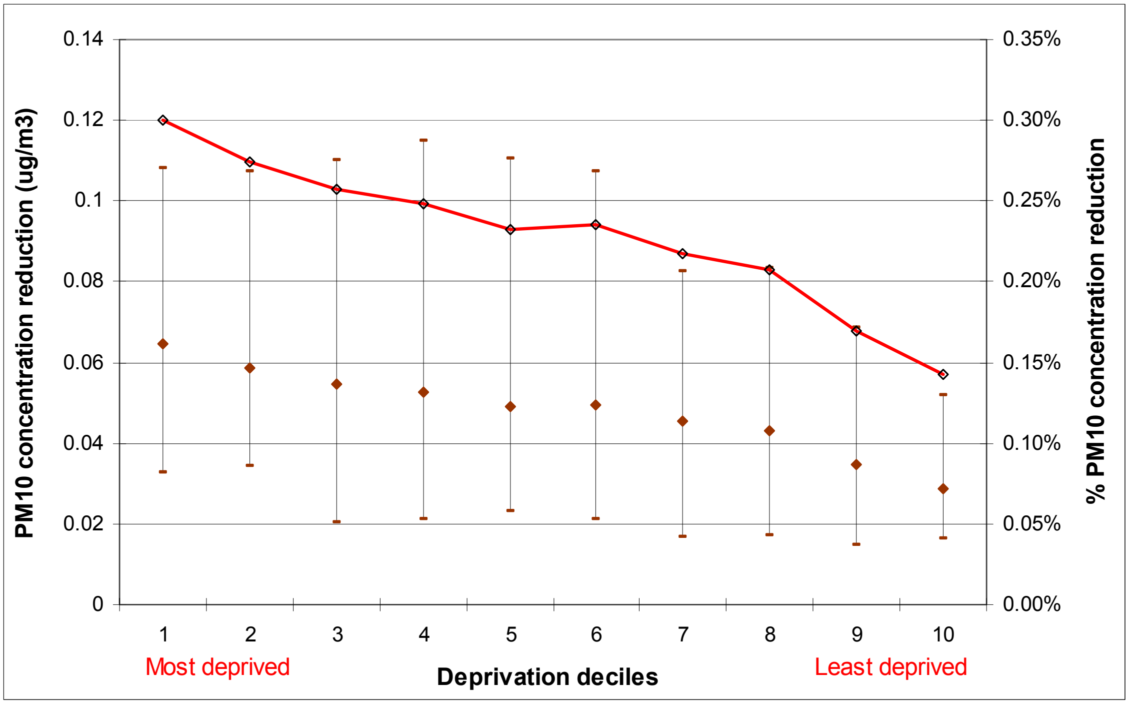


Figure 5.3 shows that the most deprived deciles experience higher average concentrations than the least deprived deciles, although the variation in values (as shown by the 5th and 95th percentiles) is high. This is because the more central London boroughs (which in general are more deprived) experience the highest concentrations, whilst the less deprived outer London boroughs have lower concentrations. This is important in itself, as it shows that poorer socio-economic areas also experience poorer air quality. This is a clear inequality in air quality between different socio-economic groups. Additionally, it could be argued that if such communities are more vulnerable to potential health effects, then the inequalities could be greater because for every $\mu g/m^3$ PM_{10} the effects are greater relative to other communities.

The question is how the proposed LEZ might affect the above trend? In Figure 5.4, it is shown that in absolute terms, it is the most deprived deciles that experience the greatest reductions (although the changes in themselves are small). In relative terms (denoted by the red trend line), the most deprived deciles benefit most, with a 0.3% reduction in decile 1 versus a 0.14% reduction in decile 10. A similar trend is seen in future years, although the trend is flatter (difference between deciles 1 and 10 less) due to ongoing improvements in air quality across all areas.

The modelled data suggests that larger reductions would occur for the most deprived communities after the possible introduction of the LEZ scheme. However, the variation in reductions is small as they are averaged out across a population group that is not geographically defined e.g. some more deprived areas will be in both areas of high and low pollution.

Figure 5.4 Change in average concentrations of PM_{10} in 2008 after possible LEZ implementation (Red trend line shows percentage reductions)



This analysis suggests that limited inequalities do exist across Greater London, in terms of the pollution experienced by different socio-economic groups. This is important, due to the potentially greater vulnerability of such groups to health impacts associated with air quality. The introduction of the proposed LEZ marginally reduces such inequalities, with a slightly higher reduction in decile 1 than in decile 10. In summary, the health benefits associated with the proposed LEZ are likely to be marginally higher in the more deprived areas. This is both because this is where reductions are highest (on average) and because this is considered a more vulnerable group.

Air quality experienced by different age groups

An analysis has been undertaken to assess the proportion of different age groups exposed to different levels of PM_{10} concentrations across London. For each age group, the number of people exposed to concentrations greater than 23 $\mu g/m^3$ has been assessed in the analysis years 2008 and 2012. The results are presented in Table 5.15 below.

Table 5.15 Proportion of different age group populations exposed to concentrations of PM_{10} greater than 23 $\mu g/m^3$

Year of LEZ scheme	Proportion of age group exposed to more than 23 $\mu g/m^3$ PM_{10}			
	Average	0-15	16-64	65+
2008 (without LEZ)	2.2%	1.7%	2.5%	1.9%
2008 (with LEZ)	2.0%	1.5%	2.2%	1.7%
2012 (without LEZ)	0.3%	0.2%	0.3%	0.3%
2012 (with LEZ)	0.2%	0.1%	0.2%	0.2%
Total population (000s)	7,171.6	1,365.3	4,914.7	891.6

From the above analysis, the potentially most vulnerable age groups – children and the elderly - to health impacts associated with air quality have lower proportions of their populations in areas where PM_{10} concentrations are highest relative to the average and adult (working age) populations.

Distributional analysis summary

There are a number of interesting conclusions that can be drawn from the above distributional analysis:

- The highest exceedence populations (for both PM_{10} and NO_2) are located in the central London boroughs. In absolute terms, it is these boroughs that see the largest reduction in exceedence populations that would occur as a result of the introduction of the LEZ. In terms of relative reductions, outer London boroughs see the largest reductions.
- Health benefits (due to reductions in PM_{10}) are highest in central London boroughs, and then in the boroughs immediately to the north, east and south.
- These tend to be where the most deprived areas of London are located. This is reflected in Figure 5.3, where average concentrations are highest in the most deprived deciles. These areas see the largest decrease from the proposed LEZ; however, this reduction is not significantly larger than seen in the least deprived deciles, and therefore the impact on health inequalities is likely to be small.
- Other vulnerable groups, determined on the basis of age, do not appear to experience on average higher concentrations of PM_{10}.

In the community profile, health statistics were provided. There does not seem to be an obvious relationship between the health statistics on illnesses associated with health impacts and areas that have higher than average levels of PM_{10}. This is because such illnesses are influenced by many other factors apart from air quality. What may be more significant is that the general health of the more deprived communities tends to be worse than in less deprived communities. This has potential implications for vulnerability to health impacts associated with air quality; this is particularly important given that the most deprived communities appear to experience higher levels of pollution.

5.1.5 Summary of health impacts associated with air quality improvements

From this analysis, it is clear that the LEZ would bring about important reductions in the health impacts associated with air pollution, and would therefore be an important part of London's overall strategy for improving air quality and limiting the associated health impacts. This is in evidence from the analysis of the number of people who are no longer in exceedence areas for NO_2 and PM_{10} after the introduction of the LEZ, and from the quantification of actual health benefits.

There are significant differences in the distribution of these benefits. Central London boroughs appear to experience the highest level of benefit due to the fact that this is where the air quality problems are most severe. These boroughs are also those that have the highest proportion of deprived communities; therefore, it is the most deprived communities that on average experience the most significant reductions. Although the relative reductions are small, this is still important given that such communities are thought to be more vulnerable to air quality impacts on health.

5.2 HEALTH IMPACTS ASSOCIATED WITH SOCIO-ECONOMIC STATUS

The introduction of a LEZ could have indirect effects on health through impacts on community socio-economic status, primarily through changes in employment status.

5.2.1 How does socio-economic status affect health?

The evidence from the literature suggests that socio-economic status can be linked to differing levels of health or *health inequalities*. In general terms, the physical and mental health of communities in more deprived areas (lower economic status) tends to be worse than in less deprived areas. This is linked to many different factors (or health determinants) including:

- Resource availability to enable healthy lifestyle choices
- Lifestyle choice
- Provision of health services
- Quality of outdoor environment and housing

In general, the socio-economic status of a community will only be changed by significant actions (large regeneration or infrastructure projects / significant increase in private investment). It is unlikely that a LEZ would have such an effect. Where the LEZ may have more significant impacts is through its impact specifically on the employment status of individuals and to some extent on local economies e.g. areas that might have a high proportion of small businesses.

Studies reviewed in the literature suggest that an unemployed status can be associated with an increased risk of mental or physical illness in the newly unemployed. Conversely, increases in employment are likely to reduce the risk.

5.2.2 How might the proposed LEZ affect socio-economic status and the health of the population?

The LEZ could impact on employment and the local economy, depending on the significance of impacts on businesses. As discussed, loss of employment or reduction in income could have implications for individual health.

A separate economic and business impact assessment has been undertaken by SDG (2006) to assess the potential impacts of the proposed LEZ on business sectors and employment. Concerning direct impacts[12] of the scheme, the analysis suggests that the introduction of the LEZ could lead to a net loss of just over 200 jobs. Adding in wider economic impacts (indirect and induced impacts arising from the direct impacts of the LEZ), the net loss in jobs could be up to 400. Without the benefits to ancillary sectors associated with the introduction of the LEZ, the impacts could be significantly higher.

[12] Direct impacts result from costs of compliance net of the ancillary economic benefits generated by the LEZ.

The transport sector is predicted to be worst affected, particularly the smaller operators who own their vehicles. Due to the competitive nature of this sector, compliance costs are less likely to be passed through but rather absorbed by the operators. The construction sector is also likely to be more affected than other sectors; again, it would be the smaller operators most affected. Coach users would also be affected through costs being passed through to ticket prices.

Ancillary sector benefits are estimated for the vehicles maintenance and repair sector, who would see additional revenues from the increase in the demand for vehicle re-engining and retrofitting of particulate traps. An increase in new and used vehicles would have benefits for the road vehicle retail sector. Small additional benefits could also be seen in the vehicle, parts and abatement technology manufacturing sectors.

In addition to these ancillary sector benefits, there may also be some additional positive economic benefits:

- The improvement in London's environment could be expected to lead to some economic benefits. Companies or individuals may value the benefits of a cleaner London. This may benefit London by influencing location decisions and stimulating employment.
- The health benefits to Londoners would result in less lost time at work from air-pollution related illness and reduce health service costs (as quantified earlier).
- If LEZs were subsequently also introduced in other cities, London-based companies might find themselves at a modest competitive advantage.

Quantification of the actual health impacts that arise from these economic impacts is difficult, and no quantification methods exist that allow for such an analysis. What is clear is that financial impacts are a small proportion of UK GVA, whilst the employment impacts are negligible when compared to the number of employees within these sectors in London. Overall, the health impacts arising from socio-economic impacts are likely to be small. More important is the distribution of economic impacts between and within sectors.

5.2.3 What is the distribution of health impacts associated with changes in socio-economic status?

From the SDG (2006) analysis, it is apparent that specific sectors could be more affected than others. Perhaps more importantly, it would be the smaller operators within these sectors, particularly those that own their own vehicles that would incur the greatest impact. In particular, the construction sector has a high proportion of small businesses – 41% of construction businesses have less than 20 employees (Watkiss et al. 2003).

Smaller operators of HGVs and LGVs would be most affected for the following reasons:

- They do not have the bargaining power of larger operators to pass costs through. In addition, they may be operating in highly competitive sectors, such as transport and storage sector, and be forced to absorb costs.
- They will tend to have smaller working capital and access to capital generally, and may find it harder to bring forward their vehicle purchase cycles. In addition, particularly for HGVs, they will tend to have older vehicles, with fewer compliant with emission standards.
- They may also operate exclusively or predominantly in London, as this is where their customer base is located, particularly small businesses using LGVs.
- With small fleets, they may not have the flexibility to switch their vehicle fleets around to ensure newer vehicles are operating in London, and older vehicles elsewhere.

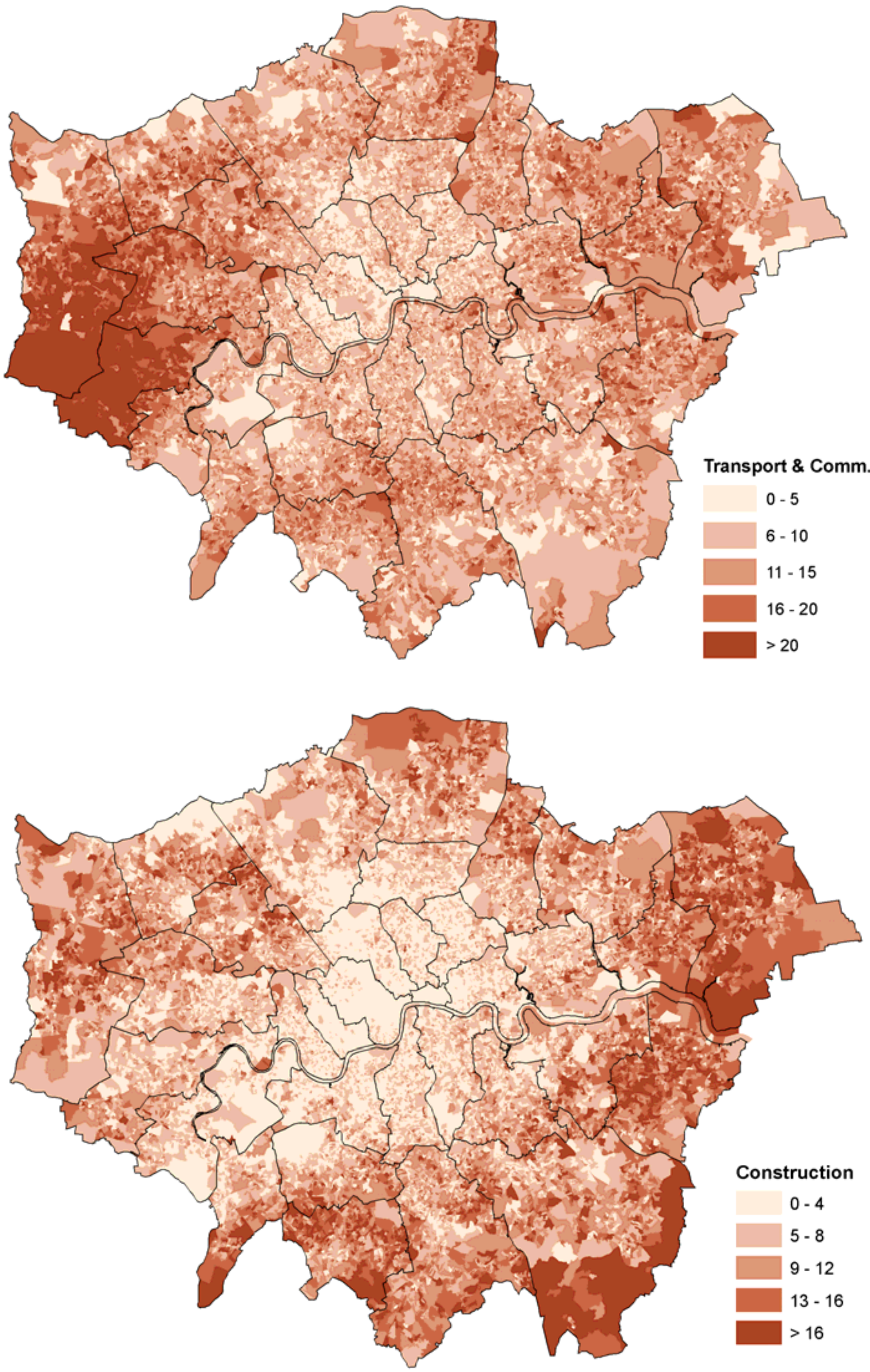
For these reasons, the additional costs from an LEZ could in some instances tip the balance between business viability and non-viability. The economic impact assessment (SDG 2006) suggests that the majority of the operators that could leave London will be smaller operators. In conclusion, the overall economic impacts both on business and employment appear small; however, these impacts may be most significant for smaller operators (private LGV owners and small HGV owner operators, who are less able to absorb the additional costs. The possible adverse impact on small businesses is also highlighted by stakeholders in the EqIA (TRL 2006).

In spatial terms, the distribution of health effects is likely to be most significant in the following areas:

- Where the employees of the most affected sectors live
- Where businesses most affected by the proposals are located
- Where levels of unemployment are already high

The construction and transport sectors have both been identified as the most affected sectors. The distribution of employees is shown in Figure 5.5 below. The data illustrate that employees in the transport sectors are concentrated in outer London, where access to the major road networks is good. This density is greatest in the west, due to proximity to Heathrow and the motorway network. For the construction sector, employees are most concentrated in the north east and south east, and other outer London boroughs.

Figure 5.5 Distribution of construction and transport, communication & storage sector employees in London



Source: Census 2001 Output Area statistics (21,400 areas) (KS11 Industry of employment), Office for National Statistics

These spatial data do not provide any indication of the size of business these employees belong to, or whether they are self-employed. Such information would provide a more accurate indication of the areas most likely to experience the greatest impacts through additional costs resulting from the possible introduction of the LEZ.

In summary, the economic assessment of the proposed LEZ has estimated a small net cost across the economy once the benefits to ancillary sectors have been taken into account. Based on this assessment, it is assumed that there could be a resulting small negative impact on health. The distribution of the effects is probably more important given that there would be differences in the impact both between sector and within sectors. In particular, it appears to be the smaller businesses and those that can't pass costs through to the consumer that would be most affected. Sectors identified include construction and transport / storage / communications.

5.3 COMMUNITY ACCESS TO SERVICES

Many different community services are provided across the public and voluntary sector to a variety of different groups, and use vehicles that could be affected by the introduction of a LEZ. Such services include transportation to enable access to different community amenities e.g. transportation for disabled groups, school buses, general bus services, or mobile services e.g. St. John Ambulance, meals-on-wheels, mobile libraries.

5.3.1 How does community access to services affect health?

Access (by transport) to jobs, goods, services and social networks can all be important for an individual's health or that of the wider community.

It is often the most vulnerable groups that require assistance in accessing services, through provision of transportation or through the provision of mobile services that bring services to the community. Without such services or a limited provision, negative impacts on well being and health of more vulnerable groups could be seen, and potential increases in inequalities in certain groups ability to access to services.

Health and well being could be affected in the following ways:

- If the ability to participate in the community becomes more limited due to less provision of community services through the voluntary and public sector, adverse impacts on well being and increasing exclusion could result
- Inability to sufficiently access healthcare services could have potential impacts on prevention and treatment of illness.

5.3.2 How might the proposed LEZ affect community service provision and the health of the population?

There may be impacts on the community access to services where vehicles, particularly minibuses and other LGVs, that provide services such as community transportation or facilitate access to services, need upgrading or retrofitting due to non-compliance. In some cases, the costs of compliance could result in a specific service being lost or downsized, or less affordable to certain groups.

Such services can be split into service provision by the public sector or community networks. Community network provision includes transportation for various community-based groups, including religious, ethnic, disabled or youth groups. A report on the economic impacts associated with the use of minibuses (SDG 2006) suggests the following

> *Larger organisations will be largely unaffected, as they tend to either operate reasonably new vehicles (with clear replacement strategies) or rent from the commercial sector / hire a vehicle and driver. Some smaller organisations tend to operate their own vehicles, some of them old and therefore unlikely to be compliant.*

The assessment suggests that smaller organisations are unlikely to continue using non-compliant vehicles, and would therefore have to upgrade, replace or hire vehicles as required. They suggest that many such organisations are not likely to continue operating vehicles but would hire when necessary.

Other community services are provided by the public sector, and include:

- Transport services provided by the public sector e.g. non-emergency ambulance vehicles or social service vehicles
- Bus services for schools within London or public bus services that may operate on the London boundary
- Vehicles used to deliver community services e.g. Meals on Wheels, St. Johns Ambulance
- Public sector service provision e.g. mobile libraries

The SDG (2006) assessment for minibus vehicles suggests that where these are owned, they tend to be newer vehicles (and are therefore likely to be compliant). In addition, the impacts would be minimal due to a significant amount of leasing or outsourcing of transportation services.

The equality impact assessment (EqIA) (TRL 2006) has also considered the potential impact on community transport, and how this might impact on vulnerable groups in society. The report states that

> *it is possible [that] it could become difficult for some community transport providers to operate within the Greater London area on the scale in which they now do. Arguably, a withdrawal of services would result in a loss of accessibility, an increase in social exclusion and possible reduction in health within the affected groups*

Potential impacts on community service provision by the proposed LEZ have been raised as significant concerns by stakeholders both in this study and in the EqIA (TRL 2006). In the HIA stakeholder meetings, a possible significant negative impact identified was the possible loss of services/amenities to disadvantaged groups e.g. the old, the disabled, who rely on services provided by Community Transport Associations (CTAs) which may not be able to afford to comply with the LEZ regulations. The types of organisations that could be affected include Age Concern, organisations catering for the disabled, social inclusion projects, and projects focusing on low-income group. CTAs provide not only access to health services but also access to other ancillary services e.g. day centres, community outings.

It was also stated that downstream healthcare costs could arise from the impacts on mental and physical well being arising from increased social isolation of vulnerable individuals and, for some such as those dependent on day centres, reduced access to quality food, warmth and general care. the contribution that community / voluntary transport schemes have on the health of the sector they serve is significant, and is growing, caused by the current policy to encourage “care in the community”. If these services are affected (reduced or removed) by the effects of the LEZ, there may be some very limited negative economic impacts on the NHS, due to a potential increase in the admission rate and severity of illness experienced by these risk groups resulting from reduced access to services.

It was also stated by stakeholders that the public sector could also be affected in a similar way to CTAs: large vehicles owned by local authorities or hospitals will need to conform to the LEZ requirements. If these organisations could not afford to replace, re-engine or retrofit their vehicles with pollution abatement technology, services could be reduced. Despite these concerns of public sector impacts, the economic impact assessment suggests that the public sector provision of services is unlikely to incur significant impacts – due to the type of vehicles that they use i.e. newer, and because services are often contracted out.

Although the possible negative impacts of additional costs were the main concern, potential benefits for users of community transport services were also highlighted in the EqIA stakeholder engagement exercise:

- Upgrading to newer vehicles would mean improved vehicle safety
- Newer vehicles might better meet the needs of users due to having improved technology e.g. vehicle access

5.3.3 What is the distribution of health impacts associated with changes to access to services?

Health impacts associated with a reduction in community access to services are likely to be most significant in the communities that rely most heavily on public and voluntary sector organisations to provide access. Such groups may include vulnerable groups such as those that are deprived, the elderly or disabled groups. These groups may be reliant on the provision of transport services or service provision that uses vehicles affected by the proposed LEZ. Services provided to the wider community (e.g. not just vulnerable groups) may also be affected, such as youth groups. Therefore, associated health impacts resulting from less service provision could affect a wider population.

Understanding the distribution of people affected is difficult due to a lack of detailed spatial data, and understanding about the actual health effects (and their severity of those effects) that might arise. In addition, it is often specific individuals within communities as opposed to communities themselves that might be significantly affected. There are some proxy datasets that can be used to identify the location of vulnerable groups, notably the elderly and deprived communities. Other groups, such as ethnic communities, can also be identified through spatial statistics. In the community profile (section 4.4), it is shown that the density of the elderly population is highest in the outer London boroughs, whilst the most deprived areas are concentrated in central London boroughs. Other groups are more uniformly distributed, whilst certain ethnic or religious groups are located in specific areas, largely for historical reasons.

In summary, it is difficult to determine where health impacts associated with a possible reduction in access to services would be most significant, due to the spatial distribution of different vulnerable groups, the lack of understanding about which services may be most affected, and what the subsequent implications for health would be.

The impact of the proposed LEZ on provision of community services is an area of concern amongst some stakeholders, based on the stakeholder engagement undertaken for this HIA and based on the findings of the Equality Impact Assessment (TRL 2006). Given the importance of some of these services to some of the most vulnerable groups in society, and the possible adverse health effects, this may be an issue that TfL could consider further prior to possible Scheme Order confirmation, particularly through the consultation with public and stakeholders.

5.4 CHANGES IN PERCEPTIONS OF THE ENVIRONMENT

Evidence from the literature review suggests that perception of improved environmental quality following the introduction of the LEZ could have a small beneficial effect on well being leading to slightly improved health status in some individuals. The perceived improvement in environmental quality might also encourage greater participation in walking and cycling giving rise to improved health in those who participate. It is, however, difficult to predict the relative importance of this effect on health as there are few relevant published data.

5.4.1 How do perceptions of the environment affect health?

Perceptions of environment quality will be affected by a range of different factors. For air pollution, such factors may include the proximity to emission sources (e.g. industrial site) or level of sources (e.g. number of cars), or visible indicators of pollution (fumes, dust etc). Another factor affecting perception could be the action that the community understands is being taken to reduce the levels of air pollution. In addition, individual awareness of pollution effects or state of respiratory health may also affect perceptions.

Evidence from the literature review suggests that health might be affected in two ways, either directly through improvements in people's well being or indirectly through the increase in activities due to perceptions of better environmental quality. Indirect health effects might arise from people cycling or walking more or less depending on their view of the levels of air pollution, or changes in the level of road safety.

5.4.2 How might the proposed LEZ change perceptions of the environment and the health of the population?

Physical signs of improved air quality are unlikely to be discernible if the LEZ were implemented, other than possibly a reduction in exhaust fumes from older high polluting vehicles. There are no changes in road traffic from an LEZ so there are unlikely to be wider perceptions of the environment changing (e.g. in relation to vehicle numbers or speed). The perception of environmental improvement is more likely to be driven by the knowledge that a LEZ has been implemented, the objective of which is to improve London's air quality. This suggests that in order to ensure that benefits associated with perceptions of air quality are maximised, it is important that the predicted benefits are communicated effectively to London's population.

It is probable that the benefits associated with improved perceptions of the environment would be small. Direct benefits may arise from improved well-being resulting from a view that London's air quality is being improved. Indirect health benefits (due to increased levels of exercise) may result from increased walking and cycling because people feel that air quality is better (or possibly that that road safety has improved (see section 5.5) though as there are no changes in vehicle numbers or speeds, this latter effect is likely to be very low).

Another small indirect benefit (which could have implications for health) could result from perceptions by overseas tourists that London's environment is being improved; increased levels of tourism may lead to increases in this sector's employment (see section 5.2 for more information on health benefits associated with employment status). A similar effect could occur from companies looking to locate to an area (e.g. London), in that a higher environmental quality might make an area more attractive (though there are other factors which have significantly more influence on investment decisions).

Changing perceptions arising from the introduction of a (air quality targeted) road transport scheme are difficult to qualitatively assess without the use of population surveys / polls. Assessment of how those changing perceptions affect health is extremely difficult. Therefore, this HIA only highlights that this is an issue that should be taken into account, and that, based on the evidence, the health benefits are likely to be small.

5.4.3 What is the distribution of health impacts associated with changing perceptions of the environment?

The distribution of any health benefits arising from changing perceptions will vary significantly across the population, based on a range of different factors. Understanding how differences in perception affect health of different communities is even more complex.

Differences in the perception of environmental improvements will be affected by:

- Proximity to sources of pollution e.g. major roads
- Ownership of a car. People who drive as opposed to cycle, walk or use public transport may be less aware of poor air quality due to less exposure to the visible signs.
- Household composition. Differences in age, health status or having children could affect perceptions of the importance of air quality
- Lifestyle factors. This could include patterns of daily movement e.g. travel to work, or work environment e.g. working outside or in office environment
- Knowledge base, whether people are aware of the current impacts of air pollution and so able to perceive the benefits of improved air quality

Differences in perceptions of the environment, and how these might change as a result of the introduction of a LEZ, could be further assessed through surveys undertaken in different parts of London. There is evidence in the literature to suggest that perceptions do differ, depending on some of the above factors, between different communities (Williams and Bird 2003; Day 2004).

There is evidence that perception is importance and can affect the health of the population, particularly in terms of well being, associated with how people view their quality of environment, and its impact on quality of life. Measuring this is difficult, particularly as perceptions within and between communities will differ significantly. On balance, it is likely that the health benefits from the improved perception of the environment would be small.

It is important that the information about environmental improvement and health benefits that are predicted from the introduction of a LEZ are communicated effectively to the population as a whole.

5.5 NOISE REDUCTION

5.5.1 How does noise affect health?

Noise is a major nuisance and is widely recognised as a disbenefit affecting daily life. It may also lead to a number of health impacts through a variety of direct and indirect effects, although there is considerable debate on the reliability of the evidence. These were discussed in the earlier literature review section (4.2). Transport is a major source of ambient noise levels and therefore may have potential amenity and wider health impacts. It is possible to assess quantitatively the noise levels from transport, but it is more difficult to evaluate quantitatively what the health consequences of these levels are.

It is stressed that road transport noise has two components. The first is noise from the engine, exhaust system and transmission and is the dominant noise source at lower speeds, particularly from heavy vehicles. The second is generated from the interaction of the tyres with the road surface and is the dominant noise source under free flow conditions at moderate to high speeds.

In assessing the impact of traffic noise on the environment, two indices for describing traffic noise levels have been developed which are found to correlate well with people's dissatisfaction with road traffic noise experienced in their homes. $L_{A10,T}$. and, $L_{Aeq,T}$.[13]

There are also inequality effects with noise. Higher noise levels tend to be associated with socially deprived groups (i.e. consistent with relationships that show that quieter houses carry a property premium). Reductions in noise are potentially greater for these disadvantaged groups. There is also some evidence that links high noise levels with effects in children, which would also mean that noise reductions might have greater benefits to these sub-groups

5.5.2 How might the proposed LEZ affect noise levels and the health of the population?

Changes in vehicle noise legislation have not followed those of exhaust emissions (Euro standards), but modern vehicles are quieter than older vehicles, due to the introduction of noise limits. These are shown below in Table 5.16.

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[13] $L_{A10,T}$ is the noise level, measured on the scale of dB(A), which is exceeded for 10 percent of a given period *T*. The 'A' in the subscript denotes that the sound has been filtered or A-weighted to correspond with the frequency response of the human ear. $L_{A10,18h}$ is the arithmetic average of the 18 values of $L_{A10,1h}$ determined over the period 0600 - 2400 on a normal weekday and is the most common noise index for road traffic assessment used in the UK.

$L_{Aeq,T}$ is the continuous equivalent noise level measured on the scale of dB(A). It is defined as the noise level which if maintained constant over the time period *T* would contain the same acoustic energy as the actual time varying sound.

Table 5.16 Noise limits for each vehicle type and date of enforcement

Vehicle type	Noise limits values and date of enforcement dB(A)		
	1996	1988/9	1970
Cars/Taxis	74	77	82
LGVs	76 – 77	78 – 79	84
HGVs	77 – 80	81 – 84	89 – 91
Buses	78 – 80	80 – 83	89 - 91

Pre-Euro (and some Euro 1 vehicles) will only comply with noise limits enforced in 1988/9 whereas Euro 2 and 3 vehicles will comply with noise limits set in 1996. The first phase of the London LEZ, which moves the vehicle fleet to Euro III standard would therefore have noise benefits (i.e. by bringing forward the replacement of pre-Euro and Euro I / 2 vehicles. The 2012 LEZ would not lead to any net change in noise levels for heavy vehicles, as these vehicles will have already been retired from the fleet. There would also be no noise benefit for the introduction of heavier LGVs, as the proportion of older vehicles would almost be negligible by 2010 (i.e. the number of pre-1996 LGVs still operating in 2010).

A LEZ only affects engine noise (unless changes in vehicle numbers also occur, e.g. from diverted traffic). The assessment of noise benefits was assessed in the detailed analysis in the Phase 2 feasibility study (Watkiss et al, 2003), which found modest noise benefits, with around a 0.3 dB(A) decrease in central London and 0.1 dB(A) increase across London. In practice, these reductions would only just be noticeable; though it is likely people would actually notice and appreciate a reduction in the maximum noise level of some of the pass-by 'events'.[14]

These noise reductions could also have small amenity benefits, although it is unlikely that these would be large, and would be unlikely to lead to any significant health benefits (from well-being, or improved perception of the environment).

5.5.3 What is the distribution of health impacts associated with noise?

While the changes in noise are low, any benefits would be greatest for people living directly alongside the road network – and this is likely to include a significant proportion of deprived communities. As some noise impacts (developmental learning) occur in children (e.g. noise disturbance in school), then any changes in noise might have more positive effects for this group – though given the level of noise reduction, this is unlikely to be significant.

[14] There are some health quantification approaches which have assessed the health impacts of noise, using exposure response functions (as for air quality above), e.g. in the EC UNITE project. (UNIfication of accounts and marginal costs for Transport Efficiency, http://www.its.leeds.ac.uk/projects/unite/) These include functions for Stress related health effects (hypertension and ischaemic heart disease), psychosocial effects (annoyance) and sleep disturbance (awakenings and subjective sleep quality). The functions are implemented above a threshold, and need detailed noise analysis to implement correctly. No quantification is proposed for the HIA here, though it is anticipated that direct health benefits would be very low.

The evidence suggests that exposure to noise can have important effects on health. However, it is estimated that the proposed LEZ would lead to only marginal reductions in noise levels, due to the introduction of newer vehicles into the vehicle stock in London; therefore, health benefits are likely to be marginal.

5.6 CHANGES TO ROAD SAFETY

5.6.1 How does road safety affect health?

In 2005, London experienced over 28,000 casualties on roads (TfL 2006). Measures to increase road safety are important to reduce the number of accidents in London, and initiatives such as *London's Road Safety Plan* are important in ensuring that increased road safety is a priority.

Road safety can be improved through the introduction of newer vehicles, which tend to have better safety features. Such safety improvements in newer vehicles have helped contribute to a reduction in casualties in the UK (DfT 2005).

5.6.2 How might the proposed LEZ affect road safety and the health of the population?

The LEZ has the potential to improve the safety of vehicles, by encouraging modern vehicles. The levels of reduction in road traffic accidents from the LEZ is, however, likely to be very low, as it does not alter traffic volumes or speeds. Despite being a small reduction, any measure that is likely to reduce the number of accidents is important in view of the Mayoral targets for accident reduction, as shown below.

Mayoral targets for reduction in accidents by 2010 (relative to the 1994-98 average)

The Mayor announced the following accident reduction targets in March 2006, to be achieved by 2010 (revising previous reduction targets that were in the main achieved):

- 50% reduction in the number of people killed or seriously injured
- 50% reduction in the number of cyclists and pedestrians killed or seriously injured
- 40% reduction in the number of powered two wheeler users killed or seriously injured (unchanged)
- 60% reduction in the number of children killed or seriously injured
- 25% reduction in the slight casualty rate, expressed as the number of people slightly injured per 100 million vehicle kilometres

Source: TfL (2006)

One additional aspect (revealed through the stakeholder consultation), was the potentially wider benefits from LEZ compliance and monitoring in identifying illegal vehicles or drivers. However, it is not considered likely that the levels of changes in accidents from the LEZ would lead to wider perceptions about safety (e.g. in relation to issues of community severance) because the LEZ is not projected to affect vehicle numbers or speeds.

5.6.3 What is the distribution of health impacts associated with changes in road safety?

The literature review suggests that reduction in the number of accidents is most likely to benefit vehicle drivers, children and potentially those in the most deprived communities. However, we consider the potential reduction in accidents resulting from the LEZ to be very small; predicting the distribution of this scale of reduction is not possible.

6 HIA findings and recommendations

This section of the HIA report presents a review of the evidence appraisal, summarising the key findings on health impacts, and prioritising the impacts in terms of significance.

6.1 SUMMARY OF FINDINGS

Air quality

The health benefits modelling estimates that there would be important reductions in the health impacts associated with air pollution, and that the proposed LEZ would be an important part of London's overall strategy for improving air quality and limiting the associated health impacts. This is in evidence from the analysis of the reduction in the number of people in areas where concentration of NO_2 and PM_{10} exceed air quality objectives after the possible introduction of the LEZ, and from the quantification of actual health benefits. It is important to stress that the health benefits would not be confined to London's population but to the wider UK population, due to the impact of cleaner vehicles used outside of the LEZ.

Using the health impact assessment methodology from the Defra Air Quality Strategy Review it is estimated that from 2005 to 2015, the emissions benefit in London from the LEZ will lead to 5,200 years of life lost gained, 43 respiratory hospital admissions avoided, and 43 cardiovascular hospital admissions avoided. Using the EC approach, a much greater additional health benefit is estimated on top of the benefits from extra years of life lost and avoided respiratory hospital admissions. It is estimated that around 310,000 cases of lower respiratory symptoms, 30,000 cases of respiratory medication use, and around 231,000 restricted activity days will be avoided from the introduction of the LEZ.

The total discounted benefits of the London LEZ schemes are estimated at approximately 200 million pounds using the Defra AQ Evaluation analysis and 420 million pounds using the EC CAFE CBA analysis. A significant proportion of these benefits result from air quality improvements outside of London.

There are significant differences in the distribution of these benefits. Central London boroughs appear to experience the highest level of benefit because that is where the air quality problems are most severe. These boroughs are also those that have the highest proportion of deprived communities; therefore, it is the most deprived communities that on average experience the most significant improvements in air quality. Although the relative reductions in air pollution are small, this is still important given that such communities are thought to be more vulnerable to air quality impacts on health.

The most important health benefits from the proposed LEZ are those associated with improvements in air quality. The benefits estimated illustrate the important impact that the proposed LEZ would have on reducing the illness associated with air pollution in London.

Socio-economic Impacts

The economic assessment of the proposed LEZ has estimated a small net cost to the London and south east economy once the benefits to ancillary sectors have been taken into account. Based on this assessment, it is assumed that there could be a resulting small negative impact on health. The distribution of the effects is probably more important given that there would be differences in the impact both between sector and within sectors. In particular, it appears to be the smaller businesses and those that are less able to pass costs through to the consumer that would be most affected. Sectors identified include construction and transport / storage / communications.

The compliance costs associated with replacing vehicles or retrofitting abatement technologies could potentially have an impact on the ability of the voluntary and public sectors to maintain community services, whether this is transportation or a service that requires the use of vehicles affected by the scheme. At this time we cannot be sure to what extent these services would be affected by the scheme. It is suggested that TfL gather further insight through the consultation process.

Access to services is a particular issue for vulnerable groups, such as the elderly, disabled or most deprived communities, who have the greatest reliance. Any reduction in services could have implications for health, in terms of physical health (e.g. provision of healthcare or healthy food), and mental health and well being (e.g. participating in the community and use of local amenities).

Perceptions of the Environment

There is evidence that perception of environment can affect the health of the population, particularly in terms of well being, associated with how people view their quality of environment, and its impact on quality of life. Measuring this is difficult, particularly as perceptions within and between communities will differ significantly. On balance, it is likely that the health benefits from a changed perception of the environment would be small.

The environmental improvement resulting from the LEZ would probably be imperceptible. Therefore perception of improvements would only be likely through knowledge that a scheme was being introduced, and effective communication as to the likely benefits to health.

Noise

The evidence suggests that exposure to noise can have important effects on health. However, it is estimated that the proposed LEZ would lead to only marginal reductions in noise levels, due to the introduction of newer vehicles (which tend to be quieter) into the vehicle stock in London; therefore, health benefits are likely to be marginal.

Road safety

Newer vehicles tend to be safer, and are part of the reason why road safety has improved. An increase in newer vehicles resulting from the proposed LEZ could lead to marginal improvements in road safety, and a resulting small benefit to health.

6.2 PRIORITISATION OF IMPACTS

We believe that the health impacts identified in this study can be prioritised on a relative basis, to provide TfL with guidance on which impacts are the most important in terms of evaluating the projected impacts of the proposed LEZ on health. Prioritisation can be based on our understanding of the magnitude of the impact, our confidence in the estimates, and the likelihood of the impact. In addition, the distribution of health impacts, particularly on the most vulnerable groups in London, can also be a factor in helping determine prioritisation.

Table 6.1 Summary of health impacts associated with proposed London LEZ

Impact on health determinant	Benefit or negative impact to health*	Relative prioritisation of impacts: - high, medium or low	Measurability / likelihood
Improvements in air quality	Quantified reduction in years of life lost (mortality impacts) attributable to PM_{10} air pollution (including both primary particles from vehicle exhausts, and secondary particles generated from NOx emissions)	H	Calculated / Definite
	Quantified reduction in morbidity (e.g. respiratory hospital admissions, restricted activity days) attributable to PM_{10} air pollution (both primary and secondary particles).	H	Calculated / Definite
	Outside of London health benefits resulting from the use of LEZ compliant vehicles outside of the zone	H	Calculated / Definite
	Non-quantified health benefits associated with reduction in pollutants other than PM_{10} (E.g. direct impacts of NO_2 and ozone - quantification more difficult but possible with available pollution data)	M	Calculated / Definite
Access to services	Cost implications of the LEZ potentially leading to a reduction in community services, with implications for health, particularly those in most vulnerable groups	M	Qualitative / Possible
Employment status	The direct and indirect economic impacts of the proposed LEZ result in a small net financial cost; therefore, a small negative impact on health is assumed. The distribution of these impacts is potentially more important.	M	Qualitative / Probable
Perceptions of environmental improvement	Small health benefits could arise from people perceiving that the environment (in terms of air quality) is improving	L	Qualitative / Probable
Reduction in noise	Small positive health benefit associated with lower background noise levels due to increase in newer vehicles	L	Qualitative / Probable
Improved road safety	Small positive health benefit associated with fewer road casualties due to increase in newer, and therefore, safer vehicles	L	Qualitative / Speculative

* Benefits shaded green; negative impacts shaded orange

6.3 RECOMMENDATIONS

The following recommendations concerned with minimising any negative impacts and maximising health benefits have been proposed to Transport for London for their consideration, based on this HIA analysis.

1. The air quality health benefits are recognised as the key health effects associated with the proposed LEZ. It is therefore recommended that TfL further develop the methodology for assessing these benefits prior to the scheme's possible implementation. This recommendation is developed further in section 7.1 on monitoring.

2. The scheme currently proposed allows older vehicles to be fitted with PM abatement technology; there is no requirement to fit NOx abatement technology. However, the recent start of Euro IV heavy-duty vehicle emissions standards means that NOx abatement technology is developing rapidly. It is therefore recommended that TfL monitors these developments and at a future date reassesses the practicalities, costs and benefits of including NOx abatement within the LEZ scheme.

3. The health benefits that have been identified through the HIA and health benefits modelling work should be effectively communicated to the wider public, so that there is a wide understanding of health benefits associated with the possible introduction of a LEZ. This is also important for people's perceptions of the proposed LEZ, and could result in further health benefits.

4. The distribution of health benefits associated with air quality improvements could also be communicated – that the most deprived communities who are most susceptible to impacts from air pollution experience the largest reductions in pollutant concentrations.

5. The detail of the LEZ scheme should be widely publicised, particularly to the businesses and community organisations that might be affected. This should be done as soon as possible, to ensure that the cost implications of the LEZ can be managed before the possible introduction of the proposed LEZ. This could help minimise the negative health impacts that could result from job losses or reduction in community service provision. One way of achieving this for heavy goods vehicles (HGVs) would be for TfL to prepare, and VOSA to distribute, explanatory leaflets at the few HGV testing stations within and adjacent to London when vehicles are presented for their annual roadworthiness (MOT) test.

6. Community service providers, particularly those who provide services to vulnerable groups, should be encouraged to respond to the consultation to establish the potential impacts, and ways that impacts might be mitigated.

This could minimise any disruption to services, and the potential associated health impacts.

7. Wider concerns on health raised through the HIA engagement process, and the other impact assessments, should be communicated widely to ensure awareness of the LEZ in different communities.

8. A monitoring strategy should be further developed to assess the actual health impacts of the LEZ post-implementation. This is discussed in greater detail in the following section.

7 Monitoring and evaluation

Monitoring of health impacts is important to assess the actual impact of the scheme. In this step of the HIA process, we suggest an approach to monitoring and the range of baseline data that would need to be collected prior to the scheme going live. We have not suggested any monitoring of actual health outcomes but other data on which the potential impacts can be judged.

In the HIA process, monitoring is concerned with how the implementation of the proposal actually affects the population's health post-scheme implementation. Health impacts associated with such schemes can be difficult to determine due to the many other factors affecting health such as lifestyle, infection, constitutional factors, and living / working conditions. In many cases, using empirical evidence is not possible to monitor health impacts. Therefore, the use of proxy statistics as opposed to data on actual health outcomes can help assess the health impacts of the proposed scheme.

In this section we also cover the evaluation of the HIA process, which considers whether the specific objectives of the HIA have been met. This has been considered in discussion with TfL, and recommendations made accordingly concerning how this could be improved or changed for future assessments. We have also commented on the strength of the analysis and our relative confidence in the results.

7.1 MONITORING

Monitoring the actual impacts of any environmental measure on the health of the population is difficult unless the change in environmental quality is very significant. An example of where a measure did produce a significant improvement in air quality, and where the impact on health was evident in the health statistics was the solid fuel sales ban in Dublin in 1990 (Clancy et al. 2002).

The impact of most measures targeting environmental improvement cannot be easily identified through health statistics because of the influence of many other factors on the population's health. This is likely to be the case with the proposed London Low Emission Zone, and therefore the collation of health statistics as part of a strategy to monitor the health impacts of the scheme has not been recommended here. We have therefore focused on recommending further refinements to the health benefits modelling.

We propose that TfL collect a range of different baseline data prior to the date of implementation of the scheme that enables them to 'estimate' the health impacts of the scheme. Depending on resources to undertake monitoring and the greater relative importance of some impacts, prioritisation for the collection of some data should be agreed.

In addition, it would be a useful exercise to follow up the stakeholder engagement undertaken for this HIA after the introduction of the proposed LEZ. It would be useful to understand whether the contributing stakeholders considered their concerns were justified, and whether they believed the perceived health benefits or any negative impacts had occurred. This would provide TfL with information about the usefulness of such stakeholder engagement exercises within an HIA, and whether concerns around health issues had been addressed.

We propose four parts to the monitoring strategy for health impacts, with a focus on the health benefits resulting from air quality improvements.

7.1.1 Air quality improvements

It has been recognised in this study that the main health benefits result from the improvements in air quality, resulting from lower emissions due to changes in the road vehicle stock in London. Analysis, as described in this report, can be further developed over the next few years to establish a more robust baseline prior to possible scheme introduction. The same analysis techniques could then be used to assess the impacts on health after implementation. Improvements to the current health benefits modelling could include the following:

- Improved emission inventories. It is understood that traffic monitoring is already underway to provide an improved understanding of the vehicle profile across different parts of the London road network. This data will feed into the emission inventories, which are an important part of the input into air quality modelling, on which the health impact assessment is largely based.

  In addition, it will be important for new knowledge of emission factors, particularly across different euro standard vehicles, to feed into the emission inventory development. This may be achieved through continuing co-operation between London Atmospheric Emission Inventory (LAEI) and National Atmospheric Emission Inventory (NAEI) activities. However, uncertainty over appropriate emission factors for HGVs, particularly for Euro IV specification vehicles which only became mandatory from 1st October 2006, may mean that some further research to establish emission factors is required.

- Improved pollution monitoring. It is understood that TfL has already expanded the pollution monitoring network, in particular to increase the measurements of $PM_{2.5}$. This is important because virtually all vehicle exhaust PM_{10} is actually $PM_{2.5}$, whereas the PM from tyre, brake and road wear, resuspension and from other non-road transport sources are predominantly in the $PM_{2.5}$ – PM_{10} range. Consequently, monitoring $PM_{2.5}$ is a more sensitive measure of PM from road transport exhaust, and will be a more sensitive measure of the effect of the LEZ on air quality. This additional data can then feed into the air quality modelling.

- Improved pollution modelling. It is important that advances in the understanding of techniques to model air quality pollution are incorporated into the methods used for the LEZ analysis.

- Improved health benefits modelling. There are number of ways that the health benefits modelling could be refined over the next few years:
  - Quantification of health impacts associated with other pollutants
  - Incorporation of developments in quantification methodologies, including better characterisation of the impacts of different particle species
  - Improved knowledge of the patterns of daily population movement to more accurately model exposure.

We recommend that the health benefits modelling approach, and the methodologies for compiling the input data, are further developed over the next few years. This is important given that the key health benefits of the scheme are those relating to air quality improvements, and that such benefits are difficult to measure empirically.

For health affects associated with noise, these can be determined from the change in vehicle stock, which will be monitored. However, the impacts are likely to be small.

7.1.2 Impacts on employment and businesses and associated health effects

The HIA analysis suggests that health, particularly mental health and well being, can be affected by employment status. The proposed LEZ is likely to have a small negative impact on the levels of employment in certain sectors, notably construction and transport. This may be offset by new opportunities in manufacturing, fitting and maintaining pollution abatement equipment. Potential changes of employment resulting from the additional costs imposed by the proposed LEZ would be distributed differently across London's communities.

It is important that impacts on employment and businesses are monitored. From such information, it should be possible to assess qualitatively the relative importance of associated health impacts. Monitoring of the economic impacts of the Scheme is planned and the secondary health effects can be assessed based on such data.

TfL will put a monitoring strategy in place to assess the actual economic changes due to the LEZ, so will take into account the baseline situation without a LEZ. As part of this strategy, changes in employment will be identified. This information could be used to assess health benefits indirectly in sectors such as retrofitting, or selling new vehicles, and the additional revenues generated for the local economy. There may also be additional jobs associated with scheme implementation.

We recommend that the employment and business benefits and possible negative impacts are monitored through surveying or other relevant methods. The secondary health benefits can be qualitatively assessed from such monitoring data.

7.1.3 Impacts on access to community services and associated health effects

From the stakeholder engagement process to support this HIA, it was apparent that there are concerns amongst providers of community services about the potential cost implications of the LEZ, and the impacts that this might have on the ability to provide services. The evidence suggests that the level of provision of community health-related services and other community based or public services that enable access to services by communities can impact on health.

We recommend that the levels of service provision across a range of public sector and voluntary service providers are monitored prior to the confirmation of the Scheme Order and following the introduction of the LEZ (should the Mayor confirm the Scheme Order). However, it is appreciated that it would not be appropriate to devote a disproportionately high level of resources at this, and consequently the monitoring would be at a semi-quantitative level.

7.1.4 Changing perceptions of the environment and associated health impacts

Perceptions of the environment can have limited impacts on well being and health. To monitor how perceptions of the environment, particularly air quality, change before and after possible LEZ implementation, surveys of different communities would be useful; many such surveys have been undertaken in the academic community. Such surveys could also identify differences in perceptions across London communities.

Changing perceptions are likely to be a factor of people's awareness of the scheme, particularly because physical changes resulting from the scheme are likely to be imperceptible. Research undertaken to assess the effectiveness of dissemination of information concerning the scheme, and the effectiveness of communicating the benefits of the LEZ could provide some indication as to general awareness about the scheme.

We recommend that some form of surveying is undertaken to consider people's perception of air quality before and after the scheme. From survey data, the implications of changing perceptions for health can be qualitatively assessed. For example, TfL may consider including some appropriate questions in the Londoner's Survey which is carried out several times a year.

In summary, we recommend that the focus of the monitoring strategy for health impacts is on refining the data inputs and methodology used in the health benefits modeling. This is because the primary health benefits of the scheme will be through improvements to air quality. A more robust methodology for this assessment is important in view of the lack of empirical data (e.g. changes in the incidence of illness) for use in monitoring. We also recommend that surveys are undertaken to enable assessment of health effects associated with socio-economic impacts and perception, although these are less of a priority.

7.2 EVALUATION

This section of the report describes whether in the view of the authors, the HIA has met the general and specific objectives, particularly those set out in the scoping phase. We also consider the robustness of the analysis, and how the experiences of undertaking this HIA could feed into future assessments.

We have evaluated the HIA process and analysis in consultation with TfL, using the following criteria:

7.2.1 Have the objectives of the HIA been met?

The primary objective of the HIA was to identify and assess the potential health impacts of the London LEZ proposal. This has been done through the use of a comprehensive appraisal methodology. In addition, objectives relating to how the HIA would be undertaken and what it included were set out in the scoping phase of the HIA. The different elements of the HIA described in the scoping report have been completed, and helped ensure the production of a comprehensive HIA.

7.2.2 How effective was the HIA process in determining potential health impacts?

The assessment process set out in the scoping phase was appropriate for the HIA of the proposed LEZ. It included the scoping phase, which recognised and built on the work undertaken in the previous assessment. It clearly set out the timescales over a short period of time that enabled all of the different appraisal elements to be undertaken, namely the literature review, stakeholder engagement, community profile, and assessment of the proposal.

7.2.3 How robust were the methodologies used for the analysis?

The analysis was as robust and up to date as it could be at this time. The main area of actual quantification was the health benefits associated with air quality improvements, using the most up-to-date quantification techniques approved by UK Government and the European Commission. For secondary identified health impacts, no quantification methodology existed e.g. perception of environmental improvement.

Additionally, this HIA attempted to understand the distribution of impacts using spatial datasets, and as a result provided a more detailed assessment of distributional impacts than HIAs undertaken before for similar schemes.

It is important that in any future assessment, new quantification techniques are considered, which can be brought in to further strengthen the methodological approach.

7.2.4 How relevant was the evidence appraised?

In addition to using appropriate methodologies, it is also important that the relevant information is appraised. The type of information used in this study differed significantly, from direct stakeholder views (stakeholder engagement), scientific literature (literature review) and spatial data (used in the community profile and health benefits modelling).

However, all these sources of data were important for developing the assessment, and feeding into the analysis methodology. Further consideration could be given to the use of spatial data in such assessment, to better understand the distribution of impacts. Of course, this is limited by data availability.

8 References

In addition to the references listed below, a comprehensive set of references quoted in the literature review can be found in Appendix 2.

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APPENDICES

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APPENDIX 1 - Stakeholder engagement

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A1.1 Workshop organisation

This appendix provides a more detailed description of the stakeholder engagement process, plus a more comprehensive overview of the results.

When organising the stakeholder meetings, we used a list of possible stakeholder contacts provided by TfL as a starting point. Our aim was to invite a range of relevant stakeholders, including health professionals (both public health and special interest organisations e.g. Asthma UK), minority groups (e.g. Age Concern), professional organisations (Institution of Civil Engineers) and public/alternative transport focus or campaigning groups (e.g. Capital Transport Campaign). In order to achieve this balanced mix of stakeholders, the initial contact list was revised, modified and significantly updated by contacting relevant organisations by phone and establishing who the relevant contacts were in each organisation. Once this initial research was concluded, invitations were emailed to approximately 100 potential consultees. Given the short timescales and to ensure a good response rate, the invitations were promptly followed up by phone calls to the stakeholders. In some cases this resulted in a further refinement of the contacts' list as alternative contacts were suggested.

This resulted in 15 stakeholders agreeing to attend the meetings, enabling two sessions to be held, and several more stakeholders expressing an interest in the topic but being unable to attend either meeting due to other commitments, and instead offering to respond in writing. Ultimately 12 stakeholders attended the two meetings, one written response was received, and a further response was obtained by telephone interview. The mix of stakeholders who attended the meetings was well balanced, containing health professionals, special interest groups and transport organisations.

The organisations providing input to the stakeholder engagement exercise were, in alphabetical order:

- Age Concern England
- Asthma UK
- British Heart Foundation
- Camden Primary Care Trust
- Redbridge Primary Care Trust
- Community Transport Association
- Croydon Primary Care Trust
- CTC Working for Cycling
- Health Care Commission
- Health Protection Agency (representatives from both the Air Pollution Unit and the North East and North Central London Unit)
- Institution of Civil Engineers
- London Borough of Richmond Upon Thames
- St John Ambulance

Prior to the meetings, all consultees were emailed the following materials together with their invitation to attend:

i) An update on the LEZ scheme following publication of the Transport and Air Quality Strategy Revisions. This document is not provided here but included a summary of the material presented in section 2 of this report.
ii) A brief note explaining the purpose of the Health Impact Assessment. This is shown in the box below.

London Low Emission Zone – Health Impact Assessment Stakeholder engagement exercise

Transport for London (TfL) have asked AEA Technology and the Institute for Occupational Medicine (IOM) to undertake a Health Impact Assessment (HIA) of the proposed London Low Emission Zone (LEZ). An overview of the current London LEZ proposal can be found in the document labelled *London LEZ Scheme Proposal [consult].pdf*.

An HIA is an important tool for assessing the potential impacts of a proposed scheme, such as a LEZ scheme, on the health of the population. The specific aims of the London LEZ Health Impact Assessment are to:

- Identify potential health benefits arising from the implementation of the LEZ;
- Suggest measures to maximise potential benefits if appropriate;
- Identify potential adverse health effects arising during the development and implementation of LEZ; and
- Identify appropriate mitigation measures that could be adopted to minimise potential adverse effects.

The main impacts of the proposed London LEZ on health are considered to be those associated with improvements in air quality. However, there is a range of other impacts, both positive and negative, that could also impact on health. These could include changes to:

- Noise levels
- Safety of road vehicles
- Levels of employment arising from scheme operation / retrofitting vehicles (positive) or increased costs of operating in London (negative)
- Perceptions of the environment e.g. that it is cleaner, thereby impacting on quality of life
- Access to services by vulnerable groups due to increases in costs, affecting quality of life and well being.

As part of the HIA process, it is important that we get the views of interested stakeholders in order to help identify the different health impacts arising from scheme introduction, to prioritise the significance of such impacts, and to consider how positive impacts can be maximised and negative impacts minimised.

We have therefore arranged for a number of HIA stakeholder meetings to be undertaken. The aims of such meetings will be to:

- Engage stakeholders in undertaking a screening exercise to identify health impacts of greatest concern or potential benefit, and population groups / geographical areas most affected
- Allow stakeholders to voice their particular concerns with regard to maximisation of the benefits or identification of disbenefits arising from the scheme.
- Provide initial feedback outlining perceived benefits and disbenefits and discuss health impacts worthy of further investigation.

We will provide stakeholders with written feedback from stakeholder meetings and inform them when the final HIA is available for further dissemination. The proposed agenda and dates for the stakeholder workshops are provided below.

London LEZ Health Impact Assessment stakeholder meetings – dates and Agenda

Stakeholder meetings will be held at TfL offices at Windsor House, Victoria Street at the following times:

Wednesday 4th October: 2-4pm
Wednesday 4th October: 6-8pm
Thus 5th October: 10am-12pm

A proposed agenda for the meetings is presented below.

No.	Agenda item
1	**Welcome and introductions**
2	**Introduction to HIA and aims of workshop**
3	**Brief overview of LEZ proposal**
4	**Group discussion on potential health impacts (**either in small groups or as plenary session depending on attendance)
5	**Prioritisation of impacts** to consider which impacts (positive or negative) are perceived to be most significant or important, and ways to maximise benefits / minimise negative impacts will be discussed.
6	**Feedback session** (if small groups have been convened)
7	**Summary of key workshop issues**
8	**Close of workshop**

If you are unable to attend one of the meetings but would like to feedback on any health related issues relating to the introduction of the London low emission zone, we have provided a stakeholder feedback sheet (*LLEZ HIA feedback questions [consult].doc*) in which you can provide a written response.

A1.2 Workshop results

The first part of this section sets out stakeholder views on the potential positive and negative health impacts arising from the implementation of the LEZ. The remainder of the section outlines the stakeholders' suggestions as to how benefits could be maximised and disbenefits minimised.

A1.2.1 POTENTIAL POSITIVE IMPACTS

1. Improvement in lung and cardiovascular health, due to decrease in air pollution.

This was identified as the main benefit of the scheme and there was a consensus among stakeholders that this benefit was of sufficient importance to justify the introduction of the LEZ. The elderly, those with asthma and those with cardiovascular illness were identified as groups most vulnerable to the adverse impacts of air pollution and therefore the groups most likely to benefit. The very large number of Londoners belonging to these groups was highlighted. Children are also believed to be particularly vulnerable to air pollution.

- *Impacts on asthma sufferers:*

There are 600,000 asthma sufferers in London. In annual MORI surveys of the UK population, it has been consistently reported that 66% of asthma sufferers say traffic fumes trigger their symptoms and 42% avoid walking in areas with fumes. The impact of current levels of air pollution in London is that people are avoiding certain areas because of traffic fumes.

It is uncertain whether traffic pollution causes asthma, but it is well established that in areas of high pollution, especially near roads, there is a higher occurrence of symptoms and the severity of symptoms is worse. The irritant effects of airborne particles may be particularly relevant to older people with asthma whose symptoms are more likely to be triggered by nonallergic irritants rather than allergens. Childhood asthma is often more strongly associated with allergy. A reduction in emissions from vehicles would be expected to lead to an improvement in the health of asthma sufferers. In summer, traffic fumes react with sunlight and form ground level ozone, which is also an asthma trigger.

Consequently, an overall reduction in vehicle emissions should lead to a reduction in symptoms in asthma sufferers. Other benefits would include an increase in use of public spaces such as shopping streets where current levels of air pollution deter those with respiratory illness.

- *Impacts on those with cardiovascular disease:*

There are 300,000-350,000 people in greater London living with heart problems. Although it is uncertain whether air pollution causes heart problems, there is clear evidence that it exacerbates pre-existing illness. These people are encouraged by

GPs to get more physical activity including walking outside, but if they live in heavily polluted areas, outdoor activities may increase their exposure to air pollution. Reducing pollution via the proposed LEZ would have the dual effect of reducing the initial stress on their condition wrought by pollution and improving their chances of getting enough exercise.

2. Increase in perceived environmental quality.

An increase in perceived environmental quality is linked to improved mental health. This was identified by some stakeholders as an extremely important potential source of benefits.

3. Increase in walking and cycling due to increase in perceived safety and environmental quality of roads.

If people perceive their environment to be more attractive they are more likely to venture out into it, and increased walking and cycling will lead to an overall health benefit for those who participate. The presence of cyclists and pedestrians creates an impression of “safety” that might encourage greater use of outdoor space.

There may be factors in certain communities, especially those prevalent in the east of London, which lead to a lower uptake in cycling than might otherwise be expected. These include cultural factors and road safety. However, this should not be allowed to detract from the overall benefits which will accrue from this aspect of the scheme.

4. Increased use of outdoor space (leading to increased health benefits) due to increase in the perceived safety and attractiveness of the local environment.

Linked to point 2 above, the increase in perceived environmental quality may lead to increased use of outdoor space for both community purposes and physical exercise, both of which have health and social benefits. It can also lead to increased sense of environment ownership and increased social and community links.

5. Speeding up the introduction of new technologies

a) Health Benefits

By enforcing the removal of old vehicles or retrofitting vehicles with pollution abatement technology, the proposed LEZ may encourage people to consider new technologies when selecting their next car. Hence this may increase sales of new, less polluting, technologies e.g. hybrid, hydrogen vehicles, and consequently speed up their introduction. This is likely to have additional air quality benefits.

b) Safety benefits

The proposed LEZ may lead to increased road safety by reducing the age of vehicles on the road (new vehicles tend to have higher safety specifications than older vehicles).

Neither of these benefits were perceived to be as important as the actual and perceived improvement in environmental quality.

6. Possible nationwide ripple effect if large organisations decide to update their national policies to reflect the requirements of the LEZ.

It is possible that nationwide organisations would decide to update their policies in line with the proposed LEZ, or that organisations decide to pre-empt other possible LEZ schemes in different parts of the country, leading to an overall reduction in emissions.

Outside London there is also the possibility that if London introduces a LEZ other cities will be encouraged to do similarly, that might currently be more hesitant or not wishing to be the first British city to introduce a LEZ. The success of the London LEZ is likely to be an important driver for the introduction of LEZs elsewhere. There was some debate among stakeholders as to the likelihood of this benefit arising and its potential importance.

A1.2.2 POTENTIAL NEGATIVE IMPACTS

1. Loss of services in the voluntary sector (community transport).

Both stakeholder engagement meetings highlighted that the principal negative impact was the possible loss of services/amenities to disadvantaged groups e.g. the old, the disabled, who rely on services provided by Community Transport Associations (CTAs) which may not be able to afford to comply with the LEZ standards. The types of organisations that will be affected include Age Concern, organisations catering for the disabled, social inclusion projects, low-income group projects. CTAs provide not only access to health services but also access to other ancillary services e.g. day centres, community outings.

In London, there are 40-50 vans across London owned by CTAs, which would be affected by the scheme. The normal purchase price for these vehicles is £20,000 each, but the cost for updating vehicles is around £40,000-60,000 each. It is anticipated that the costs of retrofitting pollution abatement technology to comply with the proposed LEZ would be £1,000-2,000 per vehicle.

The 25 CTAs in London serve 1 million people. For example in Brent, 4 vehicles funded by the Local Authority provide 16,000-17,000 trips per quarter, with average trip length being 4-5 miles (point to point, not including distance from vehicle depot to pickup point).

The standard life span of vehicles is 15-20 years, so vehicles purchased in 2001 will still have 5-10 years in 2010. Removing these vehicles from circulation due to an economic inability to replace or modify them will have serious health and welfare implications for those people who use them. There are likely to be downstream healthcare costs arising from the impacts on mental and physical well being arising from increased social isolation of vulnerable individuals and, for some such as those dependent on day centres, reduced access to quality food, warmth and general care.

For small organisations such as most CTAs, raising the capital to replace their 2 or 3 vehicles will involve raising a sum equivalent to their annual turnover – making it an onerous or impossible task. Statutory funding tends to cover only maintenance of vehicles, and non-statutory funding is increasingly hard to obtain. With the general trend towards statutory funding being cut, this situation will only become worse. Additionally, cuts in statutory funding for NHS trusts means that NHS services are increasingly reliant on the services provided by the voluntary sector (e.g. transport to enable people to attend outpatient appointments).

There are also issues with regards to different classes of vehicles: M1 versus M2 class of vehicles. Minibuses are M2 vehicles because they have seating for more than nine passengers. Many specialist minibuses started their life as an M1 van, and were then converted for their new role. Consequently, some minibuses, even though they now have 16 seats, are still classified on the DVLA database as M1 vehicles. This has led very occasionally to reports of fines being inappropriately levied within the Congestion Charging zone. Anxiety was expressed that a similar mix-up could occur with the LEZ leading to time consuming bureaucracy to resolve, detracting from organisations' ability to carry out their principal role of providing caring services.

The contribution that community/voluntary transport schemes have on the health of the sector they serve is significant, and is growing, caused by the current government trend for "care in the community". If these services are affected (reduced or removed) by the effects of the proposed LEZ, there could be a negative economic impact on the NHS, with increased health needs of groups resulting from lack of access to services. In addition, the positive health impacts of reduced emissions may be directly counteracted by the negative effect of reduced mobility upon these groups.

St John Ambulance provide cover regularly for London events e.g. sporting events, demonstrations, Royal events, Lord Mayor events. St John Ambulance have 250 vehicles in London, of which 18 are mobile hospitals (coach-sized vehicles) and the majority of the rest are standard size ambulance vans. The cost of replacing the mobile hospitals would be £250,000 each. The cost of retrofitting to these vehicles would be £3,000-£5,000.

If the LEZ were to be implemented without exemptions to account for these emergency vehicles, these costs would be unable to be met, and St John Ambulance would have to stop providing cover to all London events. If alternative cover could not be found this would lead to events being cancelled on health and safety grounds.

2. Loss or displacement of services in the public sector transport.

The public sector could also be affected in a similar way to CTAs: large vehicles owned by local authorities or hospitals will need to conform to the LEZ requirements. If these organisations cannot afford to replace, re-engine or retrofit their vehicles with pollution abatement technology, services are likely to be reduced. Unlike in the community / voluntary sector, where organisations may have to cut services altogether, in the public sector the most probable impact is that services are likely to be reduced or other services cut. Examples of services provided by local authorities include meals-on-wheels, whilst examples of services provided by NHS trusts include a) direct emergency services e.g. ambulances, which are less likely to be cut through criticalness of need, and b) Loans of materials e.g. health displays, sexual education materials etc, to organisations such as schools, community groups etc. There would also be an increase in costs for NHS logistics more generally that could lead to a downstream reduction in funding for patient care.

Dial-a-ride services could also be affected.[15] Dial-a-ride is a TfL-funded mobility service for disabled people which aims to enable everyday activities e.g. shopping trips (it does not provide access to NHS services, since this is covered by the NHS itself). Therefore any negative effects upon Dial-a-ride services would also lead to a loss of services/amenity to a vulnerable group.

3. Economic impacts to small businesses.

There would be likely to be an impact upon small businesses owning vehicles affected by the LEZ. Economic constraints mean that these businesses may be unable to replace or upgrade their vehicle/s, and may therefore be forced out of business. This will lead to job losses, and will have knock-on economic and social effects in already-deprived communities, where these small businesses are more likely to be found. It may also lead to loss of local shops and other services in communities that are already under stress.

4. Increased visual and physical street clutter from new signage.

The signage and cameras required by the proposed LEZ could lead to increased visual and physical clutter on the street. This is of concern for specific groups, e.g. the blind/visually impaired/those using guide dogs, since it can increase stress and hamper their mobility. It also has a more general knock-on effect of reducing the perceived quality of the environment to the public in general.

5. Increased number of vehicles on the road.

The proposed LEZ scheme may lead to organisations having more vehicles on the road. For example Dial-a-ride services are already shifting away from using minibuses to using multi-purpose vehicles (MPVs). The LEZ could further encourage this because MPVs would not be affected whereas minibuses would. This would lead to more trips overall since the seating capacity is smaller. Therefore the overall impact will be more vehicle kilometres being driven, generating more emissions.

6. Increased number of large vehicles on the roads.

Some companies may choose to replace several LGVs with fewer larger HGVs to cut costs. Larger vehicles reduce safety for cyclists and pedestrians. The presence of

[15] It is the understanding of TfL that Dial-A-Ride services would not be affected by the LEZ.

large HGVs on the road is intimidating for cyclists and pedestrians and may discourage participation in cycling and walking.

7. Displacement of emissions/more polluting vehicles outside of London.

The implementation of the proposed LEZ could result in the displacement of pollution outside of London by the following mechanisms: nationwide organisations relocating their non-compliant vehicles outside of London, and other organisations selling their non-compliant vehicles to organisations located outside London.

Also, if the proposed LEZ could lead to vehicles being scrapped / retired from the road earlier than they otherwise would have been, this may lead to an increase in pollution if the life-cycle emissions of producing vehicles are taken into account.

8. Unintended consequences not picked up elsewhere.

Any other consequences which have not been foreseen. Stakeholders were concerned that it was impossible to predict the unexpected and therefore to prevent unintended consequences. Concern was expressed that businesses might find ways of conforming to the requirements of the LEZ that actually led to a greater level of environmental harm than would have arisen in the absence of the LEZ.

A1.3 How to increase identified health benefits

1. Adopt an Integrated approach.

a) Integrate the LEZ with other policies

It was strongly felt that an integrated holistic system approach encompassing all aspects of transport and health should be implemented. For example, encouraging people to walk/cycle should take into account that a factor predisposing people against walking and cycling is how safe/comfortable they feel doing so. It is likely to be far more productive to encourage people to walk/cycle whilst providing a more safe, pleasant environment for them to do so. Such an approach favours implementing the LEZ, provided that the air quality benefits of the LEZ are well publicised. It was recognised that particular support is need to promote walking and cycling in some more deprived communities and some ethnic groups.

There are also links between road safety and perceived environmental quality: the Healthcare Commission has carried out research showing that parents fear harm to their children on/near roads from vehicle/pedestrian accidents, especially major roads like the North circular, and are therefore less likely to take/allow children out. If this perception could be changed through the introduction of the LEZ and other accompanying measures, children‘s health may improve as a result of increased activity levels gained from outdoor play and increased walking and cycling. There might also be wider benefits for children's welfare, if a perceived environmental improvement leads to parents allowing children a greater level of independence.

b) Increase scope of LEZ: vehicles covered

Various suggestions were put forward in this category, including:

- The inclusion of cars, rail and aviation in the LEZ,
- The use of other fiscal measures to reduce emissions from rail and aviation,
- A programme of targeted investment in rail infrastructure outside of London in order to enable freight transport which currently goes through London by road to be diverted from road to rail and to bypass London altogether.

c) Increase scope of LEZ: pollutants covered

One stakeholder suggested that the scope of the LEZ could be widened in the future to include not just PM_{10} but the smaller particles $PM_{2.5}$ as well (although in practice, the measures to control PM_{10} emissions would lead to a concurrent reduction in $PM_{2.5}$). In addition, it was questioned whether the scheme could be extended beyond considering PM to cover NO_X (NO_2) emissions.

2. Education, promotion and public awareness campaign for the LEZ.

It is extremely important to ensure an appropriate education campaign is put in place well before the LEZ is implemented, should it be confirmed, so that, for example, all community groups are aware of the expected benefits to health and are not caught unawares with respect to compliance, and therefore negatively influenced.

It was felt to be important that the LEZ scheme is seen to be fairly implemented, i.e. affecting government/public sector vehicles, and not just unfairly targeting private business.

3. Use fiscal measures to maximise benefits.

It was felt by one stakeholder that the charges levied upon non-LEZ-compliant vehicles in London should be increased over time, to avoid people integrating them into their normal operating costs as simply-another-tax (in the way that some view the congestion charge currently).

A1.4 How to decrease identified health disbenefits

1. Use of fiscal measures to minimise a) displacement of pollution outside of London, and b) avoid community effects.

It was felt quite strongly by many stakeholders that the LEZ would only be seen as successful overall if it allowed community / voluntary organisations to continue their socially important work. The options suggested were either:

a) exempting them from the scheme,
b) providing funding to help them comply with the scheme, or
c) allowing a phased introduction.

In addition considering the exemption or phased introduction for all emergency vehicles was viewed as important.

2. Continuous review to monitor and identify and manage any unintended consequences

Although the majority of stakeholders were very concerned about potential unintended negative impacts, none of the stakeholders came up with any specific follow up actions which could be put in place once the LEZ had been implemented.

3. Use existing signage (to avoid increase in street clutter)

There is potential for the existing signage for the London lorry control scheme to be shared, eliminating the potential problem of increased visual/physical clutter.

4. Good-quality robust pollution modelling and monitoring

There were concerns as to whether there is currently enough knowledge to be certain whether the LEZ will have an important impact on air quality that will give rise to improved health. It was pointed out that it will be virtually impossible to differentiate health effects from the proposed LEZ from health effects derived from the public smoking ban which will come into effect at a similar point in time.

It is also unclear whether there will be proportionally greater health effects upon those in lower income groups, who will have lower health overall to start off with. Studies in the US have found such a link, but this will not necessarily be the case in the UK.

Stakeholders did not believe that lack of knowledge was a reason not go ahead with the LEZ, but felt that efforts should be made to ensure good pollution modelling and to extend this modelling to include pollution levels outside of London resulting from emissions generated in London, and also the impacts of emissions that may be displaced outside of London to other areas as a result of the export of noncompliant vehicles out of the London area. Stakeholders were concerned that the modelling should be based on relevant weather patterns that take account of climate change in order to properly understand the impacts of the LEZ on regional air quality.

APPENDIX 2 - Literature review

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A2.1 Introduction

The aim of this literature review was to determine what evidence was available from published studies that would help in the prediction of the nature and magnitude of health impacts arising from implementation of the proposed LEZ. A number of specific issues were addressed:

Air pollution

- Evidence linking traffic emissions to adverse health effects, the nature of any health effects specifically associated with traffic pollution and by inference the health improvements that would be expected following a reduction in exposure;

- The effectiveness of measures (LEZ or other) to reduce air pollution and other environmental improvements in actually giving rise to a measurable improvement in health;

- Information about who is most vulnerable to the adverse effects of air pollution (and therefore who is most likely to benefit from the implementation of the LEZ);

Perception of environmental quality

- The importance of perception in determining the influence of environment on health and the extent to which a perceived improvement in environmental quality might lead to health benefits;

Socio-economic and other effects

- The relationship between changes in socio-economic and/or employment status and health in order to understand the potential impacts on health that might arise if the LEZ were to adversely affect some small businesses;

- Effects of noise and, therefore, the likely effects of a small reduction in noise exposure on health;

- The potential impacts of improved road safety in reducing traffic accidents and the groups most likely to benefit.

The review is divided into three main sections addressing air pollution, perception of environmental quality and socio-economic and other effects. Within each section, each subsection comprises a review of the relevant literature and a statement about the implications of the findings from the published literature for the prediction of effects arising from implementation of the LEZ.

A2.2 Air pollution and health

A2.2.1 INTRODUCTION

The adverse health effects of exposure to air pollution have been extensively studied and the World Health Organization (WHO, 2005) have recently specifically reviewed the health effects of transport-related air pollution within the overall framework of the Clean Air for Europe (CAFE) programme, updating an earlier review undertaken in 2000 (WHO, 2000a). Two major US studies have established that long term exposure to airborne particles is established with an increased risk of mortality from cardiovascular or respiratory diseases or lung cancer and an associated shortening of life expectancy (Pope et al, 2002). The concentration-response information from the Pope et al (2002) American Cancer Society study was used as the basis of the quantification functions developed for the CAFE programme and for regulatory impact analysis in the UK. Similar effects have also been reported in Europe.

A large number of studies have demonstrated increased risks of emergency admission to hospital for respiratory and cardiovascular illnesses following short term elevations in concentrations of airborne particles and there is weaker evidence linking increased levels of nitrogen dioxide (NO_2) to increased risks of hospital admission. These include studies undertaken in London and other UK cities (Atkinson et al 2001; Anderson et al 2001; Prescott et al, 1998; Anderson et al, 1997; Anderson et al, 1995; Walters et al 1995). Other studies in undertaken in London have demonstrated relationships between increased levels of air pollution and GP consultations.for respiratory illness (Hajat et al, 1999). Studies undertaken and there are less well established relationships linking exposure to air pollution to respiratory symptoms and mild illness that may lead individuals to modify their daily routine (restricted activity days).

Although the numbers of individuals experiencing increased respiratory symptoms as the result of air pollution are likely to be considerably greater than those admitted to hospital or seeking primary care, there is considerable uncertainty in the estimation of effects. This reflects the difficulties in defining the health endpoints of interest, in actually identifying a study population and gaining co-operation to undertake studies and the very large number of different influences on respiratory health. The exposure-response relationships that have been used in the quantification of the benefits likely to arise as a result of implementation of the LEZ are those that have been used in regulatory impact analysis for COMEAP and work for the UK Air Quality Strategy, and Reviews, and at a European level in the CAFE programme.

There have been a large number of studies that have attempted to specifically link traffic emissions to adverse effects rather than air pollution more generally and these are reviewed below. A large proportion of these studies have examined respiratory effects in children. This partly reflects specific concern about the vulnerability of this group, but it may also reflect the relative ease with which it is possible to conduct studies in representative samples of school children as opposed to adults. Other studies have examined effects on birth outcome, cancer risk, and cardiovascular and respiratory health in adults.

A2.2.2 SPECIFIC ROLE OF TRAFFIC POLLUTION IN THE RELATIONSHIP BETWEEN AIR QUALITY AND HEALTH

A2.2.2.1 Respiratory effects in children

Overview

A large number of studies of the impacts of exposure to traffic pollution on the respiratory health of children have been conducted. A number of studies have reported associations between exposure to traffic pollution and respiratory illness in children, although many of these studies report inconsistent findings in relation to different indices of traffic exposure. Most studies have focussed on the prevalence and incidence of respiratory symptoms in relation to exposure to traffic pollutants and a smaller number of studies have investigated whether exposure to traffic pollution is associated with an increased asthma risk. Only a small proportion of the available studies have been conducted in the UK.

UK studies

Short term effects: In a case-control study of hospital admissions for asthma and respiratory illness among children aged 5-14 yrs in north-west London, Wilkinson et al (1999a) found no association between risk of hospital admission and exposure to traffic pollution as assessed by distance of residence from nearest main road or roads with peak hour traffic >1000 vehicles or in terms of traffic volume within 150m of residence.

Long term effects: Venn et al (2002) investigated the relation between proximity of the family home to the nearest main road and the risk of wheeze in the past year in a case-control sample of 6,147 primary schoolchildren (age 4 to 11 yr) and a random cross-sectional sample of 3,709 secondary schoolchildren (age 11 to 16 yr) in Nottingham. Among children living within 150m of a main road, the risk of wheeze increased with increasing proximity by an odds ratio (OR) of 1.08 (95% confidence interval [CI] 1.00 to 1.16) per 30-m increment in primary schoolchildren, and 1.16 (1.02 to 1.32) in secondary schoolchildren. Most of the increased risk was localized to within 90m of the roadside and among primary school children; effects were stronger in girls than boys. In an earlier cross sectional questionnaire survey of 22,968 primary school children (age 4-11) and 27,826 secondary school children (age 11-16)

In the Nottingham area, Venn et al (2000) found not relationships between traffic activity in the school locality and wheeze within the last year, cough or asthma diagnosis. There were, however, positive but non-significant dose related effects of traffic activity on wheeze severity in primary and secondary children and on persistence of wheeze in a longitudinal cohort.

Studies elsewhere (long term effects)

Traffic – all types: In a school-based, cross-sectional study in the San Francisco Bay Area in 2001, Kim et al (2004) found differences in current bronchitis symptoms and asthma in children that were related to differences in concentrations of traffic pollutants in their school environment. Among those living at their current residence for at least one year, the adjusted odds ratio for asthma in relationship to an interquartile range (IQR) in oxides of nitrogen (NO_x) was 1.07 (95% CI, 1.00-1.14). In a study of 208 children from ten southern California communities, the lifetime history of doctor-diagnosed asthma was associated with outdoor NO_2, a marker of traffic pollution. The odds ratio (OR) was 1.83 (95% CI=1.04-3.22) per increase of one interquartile range (IQR=5.7 ppb) in exposure (Gauderman et al, 2005). Increased asthma risk was also associated with closer residential distance to a freeway (1.89 per IQR; 1.19-3.02) and with model-based estimates of outdoor pollution from a freeway (2.22 per IQR; 1.36-3.63). These two indicators of freeway exposure and measured NO_2 concentrations were also associated with wheezing and use of asthma medication. Asthma was not associated with traffic volumes on roadways within 150 metres of homes or with model-based estimates of pollution from roads other than freeways.

In a study of children (aged 5-7) in kindergarten and first-grade in 13 schools in Anchorage, Alaska, Gordian et al (2006) derived an exposure measure based on traffic density within 100 m of the cross streets closest to the child's residence. After controlling for individual level confounders, the relative risk of having an asthma diagnosis were 1.40 (95%CI 0.77, 2.55) and 2.83 (1.23,6.51) in the medium and high exposure groups relative to the low exposure group. Children without a family history of asthma were more likely to have an asthma diagnosis if they resided in a high traffic area than children who had one or more parents with asthma.

In a four-year cohort study of 2,506 schoolchildren in eight Japanese communities, Shima et al reported that the prevalence of asthma was higher among girls who lived less than 50m from trunk roads (roadside areas) than among girls in the other areas studied. The prevalence of asthma among girls increased significantly with increases in the concentration of air pollution in each area. Among boys, the prevalence of asthma did not differ in relation to the distance from roads, although the rate was higher in urban areas than in rural areas. The incidence of asthma during the follow-up period significantly increased among boys living in roadside areas relative to rural areas (odds ratio = 3.75; 95% confidence interval: 1.00-14.06). There was a non-significant increase in asthma risk in girls (odds ratio = 4.06; 95% CI: 0.91-18.10).

In a study of 7,509 European school children, Nicolai et al (2003) reported that traffic counts were associated with current asthma, wheeze and cough. In children with tobacco-smoke exposure, traffic volume was additionally associated with allergic sensitisation as assessed from a positive skin-prick test. Cough was associated with soot, benzene and NO_2, current asthma with soot and benzene, and current wheeze with benzene and NO_2. No pollutant was associated with allergic sensitisation. It was not possible, however, to exclude the possible effects of socio-economic factors associated with living close to busy roads.

In a study in a low-income population in San Diego County, California, English et al (1999) examined the locations of residences of 5,996 children [less than/equal to] 14 years of age who were diagnosed with asthma in 1993 and compared them to a random control series of non-respiratory diagnoses (n = 2,284). No significant association was found between the prevalence of asthma and traffic flow at the highest traffic street, nearest street or total of all streets within a 550ft buffer region. However, among cases, those residing near high traffic flows (measured at the nearest street) were more likely than those residing near lower traffic flows to have two or more medical care visits for asthma than to have only one visit for asthma during the year. In a study of 843 children in eight non-urban Austrian communities, Studnicka et al (1997) reported a relationship between outdoor NO_2 (considered a proxy for traffic-related air pollution) and the prevalence of asthma and respiratory symptoms.

In a study of 317 children of nine years of age living near major roads in two urban areas and one suburban area of a city in western Germany, Kramer et al (2000) reported that atopic sensitization was related to outdoor NO_2 (a marker of traffic pollution) with an odds ratio for the association between symptoms of allergic rhinitis and outdoor NO_2 of 1.81 (95% CI = 1.02-3.21). When the analysis was restricted to urban areas, hay fever, symptoms of allergic rhinitis, wheezing, sensitization against pollen, house dust mites or cats, and milk or eggs were associated with outdoor NO_2. No relationship was found with personal exposure to NO_2 which is heavily influenced by indoor sources of exposure, suggesting the outdoor NO_2 levels were acting as a proxy for traffic pollution.

Brauer et al (2002) examined the relationship between traffic-related air pollution and the development of asthmatic/allergic symptoms and respiratory infections in a birth cohort (n approximately 4,000) study in The Netherlands. Adjusted odds ratios for wheezing, physician-diagnosed asthma, ear/nose/throat infections, and flu/serious colds indicated positive associations with air pollutants, some of which reached borderline statistical significance with possibly stronger associations with traffic, for asthma that was diagnosed before one year of age.

In a study of 1,756 infants in Germany, Gehring et al (2002) reported that estimated average exposures to traffic pollutants ranged from 11.9-21.9 $\mu g/m^3$ and 19.5-66.9 $\mu g/m^3$ for $PM_{2.5}$ and NO_2, respectively. Significant associations between these pollutants and cough without infection (odds ratio (OR) (95% CI): 1.34 (1.11-1.61) and 1.40 (1.12-1.75), respectively) and dry cough at night (OR (95% CI): 1.31 (1.07-1.60) and 1.36 (1.07-1.74), respectively) were found in the first year of life but these relationships were attenuated in the second year of life. In a case-control study conducted in five French metropolitan areas, Zmirou et al (2004) investigated 217 pairs of matched 4-14 years olds with and without asthma. Lifelong exposure to traffic exhausts, as assessed from retrospective information on traffic density close to all home and school addresses was not associated with asthma whereas a significant association was found for exposure before the age of three.

Heavy vehicles: The results of several studies suggest a specific association between heavy vehicles and respiratory illness. In a study of children less than 1 year of age, Ryan et al (2005) reported that living very near (<100 m) stop-and-go bus and

HGV traffic (<50 miles per hour,<100 m) was associated with a significantly increased prevalence of wheezing (adjusted odds ratio, 2.50; 95% CI, 1.15-5.42) when compared with unexposed infants. Infants living less than 400m from a high volume of moving traffic, however, did not have an increased prevalence of wheezing.

Behrens et al (2004) reported relationships between self-reported exposure to HGV traffic and respiratory symptoms (wheezing and rhinitis) and diagnoses of asthma and hay fever. Data were collected from representative school-based samples in Muenster, Germany (n=7345) of 6-7 and 13-14yr olds. In 13-14yr olds, for exposure levels categorized as rare, frequent, and constant compared with 'never', the sex-adjusted prevalence ratios were 1.29 (95% CI = 1.08-1.53), 1.58 (1.29-1.94), and 1.57 (1.18-2.10) for wheeze in the past 12 months, and 1.20 (1.06-1.34), 1.35 (1.17-1.55), and 1.69 (1.42-2.0) for rhinitis symptoms in the past 12 months. Prevalence ratios in 6-7-yr-olds and results for a diagnosis of asthma were less consistent while no positive association was detected between hay fever and HGV traffic in both age groups. When analyses were based on a more general traffic indicator (self-reported traffic noise), no consistent associations were observed.

A case control study undertaken in New York State that compared 417 white children aged 0-14 years who were admitted to hospital for asthma and 461 children in the same age range admitted during the same time period for non-respiratory diseases, found that children hospitalized for asthma were more likely to live on roads with the highest tertile of vehicle miles travelled (VMT) (odds ratio (OR): 1.93, 95% CI: 1.13-3.29) within 200 m and were more likely to have HGVs and trailers passing by within 200 m of their residence (OR=1.43, 95% CI: 1.03-1.99) compared to controls (Lin et al, 2002). However, childhood asthma hospitalization was not significantly associated with residential distance from state roads, annual VMT within 500 m, or whether HGVs or trailers passed by within 500m.

In a population based survey of 39,275 subjects in ten areas of northern and central Italy (autumn 1994 to winter 1995) in two age groups (6-7 and 13-14 years), Ciccone et al (1998) reported that current respiratory disorders were positively and consistently associated with frequency of lorry traffic, particularly the most severe bronchitic and wheezing symptoms: persistent phelgm for > 2 months (1.68; 1.14 to 2.48), and severe wheeze limiting speech (1.86; 1.26 to 2.73). No or weaker associations with heavy vehicular traffic were detected in urban and rural areas and no increased risks were found in the whole sample with the reported traffic density in the zone of residence. In a study of Dutch children attending 24 schools located within 400m from busy motorways, Janssen et al (2003) reported that respiratory symptoms were increased near motorways with high HGV but not high car traffic counts. Lung function and bronchial hyper-responsiveness were not related to pollution. Sensitization to pollen increased in relation to HGV but not car traffic counts. The relation between symptoms and measures of exposure to (HGV) traffic-related air pollution were almost entirely restricted to children with BHR and/or sensitization to common allergens.

In an earlier study, pulmonary function tests and questionnaires were obtained from 1,092 and 1,068 children respectively in six city districts near busy motorways in the province of South Holland (de Hartog et al, 1997). Both lung function and symptoms were associated with lorry traffic density on the motorway and associations were found between black smoke concentrations (representative for diesel soot) and lung function as well as respiratory symptoms. There was no association between passenger car traffic counts or NO2 and lung function or respiratory symptoms. In a study of Dutch school children, Brunekreef et al (1997) reported that function was associated with HGV traffic density but was less strongly associated with automobile traffic density. The association was stronger in children living closest (< 300 m) to the motorways. Lung function was also associated with the concentration of black smoke, measured inside the schools, as a proxy for diesel exhaust particles. Cough, wheeze, runny nose, and doctor-diagnosed asthma were significantly more often reported for children living within 100m of a freeway than other children (van Viet et al, 1997) and HGV traffic intensity and the concentration of black smoke measured in schools were found to be significantly associated with chronic respiratory symptoms. These relationships were more pronounced in girls than in boys.

Negative studies: A number of studies have failed to find convincing associations between exposure to traffic pollution and respiratory illness in children. In a Taiwanese cross sectional study, Yang et al (2002) found no significant difference in respiratory symptoms in 3,221 children attending a school located in the vicinity of 150m from the highway compared with those in 2,969 children attending a school 1500m from the highway,

Conclusions

Overall, the results of published studies suggest that there is a weak association between exposure to vehicle emissions as assessed through residential proximity to heavy traffic and respiratory symptoms in children. Most studies suggest an increase in risk of about 20-30% for children living near heavily trafficked roads compared with other children, although the results of some studies suggest a much greater relative risk, whereas other studies have tailed to detect an effect. There is also evidence to support a possible association between exposure to traffic pollution and the prevalence of asthma and limited evidence that suggests that exposure to traffic pollution may increase the likelihood of children becoming sensitised to a range of allergens that may give rise to respiratory symptoms.

The results of a number of studies indicate that effects are most strongly associated with HGV traffic and that therefore the benefits of reducing emissions from heavy vehicles would be disproportionately greater than those arising from reducing traffic emissions more generally. There are limited data that suggest that respiratory effects arising from exposure to traffic pollution may be greatest in very young children and that exposure during very early childhood may have long term impacts on respiratory health. Adverse effects do not appear to be confined to those with asthma.

A2.2.2.2 Respiratory illness in adults

In a Canadian study, Lwebuga-Mukasa et al (2004) found an association between increased commercial traffic volume and increased health care use for asthma.

Residential proximity to commercial traffic was associated with increased prevalence rates and health care use rates for asthma.

In a study of 6,896 German adults, living at extremely or considerably busy roads (23.9% of total study population) compared to roads with no or rare traffic (64.5%) was statistically significantly associated with chronic bronchitis (adjusted OR 1.36 (95% CI) (1.01-1.83)) while nocturnal coughing attacks (past 12 months) (1.24 (0.98-1.57)), wheeze during the past 12 months (1.21 (0.93-57)), and hay fever (1.16 (0.94-1.42)) were marginally, but not significantly increased (Heinrich et al, 2005). No increased risks were found for asthma (0.97 (0.67-1.42)) and allergic sensitization (1.05 (0.91-1.20)). In a relatively simple study, in which 26 patients sat for 30 minutes beside a road with heavy traffic, Kimata et al (2004) demonstrated that exposure to road traffic enhanced allergen-induced, but not histamine-induced, skin wheal responses in with atopic eczema/dermatitis syndrome, while it had no effect on skin wheal responses in 26 normal subjects.

In a study of respiratory symptoms and pulmonary function in 55-year-old women, women living less than 100m from a busy road also had a significantly decreased lung function and COPD was1.79 times more likely (95% CI 1.06-3.02) than for those living farther away (Schikowski et al, 2005). There was a similar, but less pronounced effect on respiratory symptoms.

In conclusion, long term exposure to traffic pollution is associated with an increased risk of respiratory illness, although it is not clear how adequately socio-economic factors have been accounted for in published studies. The increase in risk of long term respiratory illness associated with living in close proximity to a major road appears to be much less than two fold.

A2.2.2.3 Cardiovascular illness/mortality

A large number of studies have examined the relationship between air pollution and cardiovascular health. The results of these studies have been used to derive the exposure-response functions used in the quantitative assessment of the impacts of the LEZ on health. In addition to studies of the impacts of air pollution from all sources, there are a number of studies that have specifically examined the impact of traffic pollution on cardiovascular health.

Short term effects: In a study of daily mortality in Amsterdam, Roemer and Wijnen (2001) reported that black smoke and nitrogen dioxide were associated with mortality (relative risk of 1.38 and 1.10, respectively, for an increase of 100 $\mu g/m^3$ on the previous day) and that effects estimates were larger in the summer and in the population living along busy roads, most probably due to exposure misclassification for populations living along busy roads. In a case-crossover study using data from southern Germany, Peters et al (2005) found an association was found between exposure to traffic and the onset of a myocardial infarction within one hour afterward (odds ratio, 2.92; 95% confidence interval, 2.22 to 3.83; P<0.001). The time the subjects spent in cars, on public transportation, or on motorcycles or bicycles was consistently linked with a substantial (twofold) increase in the risk of myocardial infarction. Adjusting for the level of exercise on a bicycle or for getting up in the morning changed the estimated effect of exposure to traffic only slightly (odds ratio for myocardial infarction, 2.73; 95% CI, 2.06 to 3.61; $P<0.001$). Although use of a car was the most common source of exposure to traffic, there was also an association between time spent on public transportation and the onset of a myocardial infarction one hour later.

Wheeler et al (2006) examined the effects of ambient pollution on heart rate variability for 18 individuals with chronic obstructive pulmonary disease (COPD) and 12 individuals with recent myocardial infarction living in Atlanta, Georgia over a seven day period. Consistent but different effects on heart rate were found in each group that were significantly associated with concentrations of ambient NO_2, interpreted as a marker of traffic-related pollution. In a panel study of 28 elderly Subjects, Schwartz et al (2005) found that $PM_{2.5}$ was associated with effects on heart rate variability, but stronger associations were seen with black carbon. Secondary particles and ozone were more weakly associated with heart rate variability. No associations were seen with SO_2 (sulphur dioxide) or NO_2. CO had similar patterns of association to black carbon, which disappeared after controlling for black carbon. Black carbon had a substantially greater effect in subjects who had had a previous myocardial. In an Italian study of 68 traffic policemen and 62 controls (all male), the traffic exposed group demonstrated a number of significant changes in cardio-respiratory measures on exercise testing (Volpino et al, 2004). Twenty-six traffic policemen and none of the controls experienced exercise-induced ECG abnormalities, hypertension or oxyhaemoglobin desaturation.

Pekkanen et al (2000) combined measured concentrations of plasma fibrinogen (a marker of blood clotability) in 4,982 male and 2,223 female office workers, collected in a cross sectional survey in London between September 1991 and May 1993, with data on concentrations of air pollution. After adjustment for weather and other confounding factors, an increase in the 24 hour mean NO_2 during the previous day from the 10th to the 90th percentile (61.7 $\mu g/m^3$) was associated with a 1.5% (95% CI 0.4% to 2.5%) higher fibrinogen concentration (and by an interference an increased risk of myocardial infarction or other serious cardiovascular event). The respective increase for CO (1.6 mgm^{-3}) was 1.5% (95% CI 0.5%, 2.5%). These associations tended to be stronger in the warm season (April to September). Significant associations were found for black smoke and PM_{10} only in the warm season. No association with fibrinogen was found for SO_2 or ozone. The effects of air pollution on cardiovascular function are not confined to the elderly or those pre-existing illness and ambient particles have been shown to affect heart rate variability in young healthy adults (Vallejo et al, 2006).

Long term effects: In a study of 189 966 stroke deaths in England and Wales (population of 19,083,979), Maheswaran and Elliot (2003) found that after adjustment for potential confounders, stroke mortality was 7% (95% CI, 4 to 9) higher in men living within 200 m of a main road compared with men living >or=1000 m away. The corresponding increase in risk for women was 4% (95% CI, 2 to 6) and the risk for men and women combined was 5% (95% CI, 4 to 7). These raised risks diminished with increasing distance from main roads.

In a Dutch study, Hoek et al (2002) found that the long term risk of cardiopulmonary mortality was associated with living near a major road (relative risk 1.95, 95% CI 1.09-3.52) and, less consistently, with the estimated ambient background concentration (1.34, 0.68-2.64). The relative risk for living near a major road was 1.41(0.94-2.12) for total deaths. Non-cardiopulmonary, non-lung cancer deaths were unrelated to air pollution (1.03, 0.54-1.96 for living near a major road). In a Canadian study of long term mortality risks, subjects living close to a major road had an increased risk of mortality (relative risk = 1.18,95% CI: 1.02, 1.38; Finkelstein et al, 2004). The mortality rate advancement period associated with residence near a major road was 2.5 years (95% CI: 0.2, 4.8). By comparison, the rate advancement periods attributable to chronic pulmonary disease, chronic ischemic heart disease, and diabetes were 3.4 years, 3.1 years, and 4.4 years, respectively. In a recent US study of air pollution impacts on mortality, Lipfert et al (2006) found that traffic density was the most important predictor of survival in US military veterans but were unable to discern which aspect of traffic (pollution, noise or stress) was of greatest importance.

Conclusions

A number of studies have demonstrated an association between exposure to traffic pollution and short-term effects on cardiac function and other studies have demonstrated longer term effects on life expectancy. In one study, the shortening of life expectancy associated with living near a main road was reported to be 2.5 years, although this seems a relatively high estimate of impact compared with other studies of the long term effects of air pollution on life expectancy.

A2.2.2.4 Childhood cancer

In a recent review, Raaschou-Nielsen and Reynolds (2006) concluded that weight of the available epidemiological evidence indicates no increased risk for childhood cancer associated with exposure to traffic-related residential air pollution. However, given the limited number of studies, the methodological limitations of both positive and negative studies and the absence of consistency in the results, it was not possible to be certain that no relationship exists. Exposure misclassification may have masked true, weak associations. Previously Langhoz et al (2002) found no evidence of an association of traffic density with childhood leukaemia in a case-control study in Los Angeles.

In another Californian study, Reynolds et al (2002) reported an insignificant increase in cancer risk in areas characterized by high vehicle or road density. Rate ratios at the 90th percentile of traffic density (neighbourhoods with over 320,700 vehicle miles travelled per day per square mile) were 1.08 (95% CI 0.98-1.20) for all cancers in children, 1.15 (95% CI 0.97-1.37) for leukaemia, and 1.14 (95% CI 0.90-1.45) for glioma. In a subsequent study of childhood cancer in California (4369 cases and 8730 matched controls), Reynolds et al (2004) found no increased cancer risk among offspring of mothers living in high traffic density areas for all cancer sites or leukaemia.

In a Danish study, Raaschou-Nielsen et al (2001) modelled the exposure to traffic of 1,989 children with a diagnosis of leukaemia, tumour of the central nervous system (CNS), or malignant lymphoma during 1968-1991, and 5,506 control children selected at random from the entire childhood population. The risks of leukaemia, CNS tumours, and all selected cancers combined were not related to exposure to benzene or nitrogen dioxide during either period. The risk of lymphomas increased by 25% (p for trend = 0.06) and 51% (p for trend = 0.05) for a doubling of the concentration of benzene and NO_2, respectively, during the pregnancy. The association was restricted to Hodgkin's disease.

In a study of childhood cancer in Denver in the 1980s, Pearson et al (2000) modelled traffic density for 1979-80 near each study home. The associations between the 750-ft-wide distance-weighted traffic density metrics and all childhood cancers and childhood leukaemia were strongest in the highest traffic density category (> or = 20,000 vehicles per day [VPD]). The odds ratio is 5.90 (95% CI 1.69-20.56) for all cancers and 8.28 (95% CI 2.09-32.80) for leukaemia. In an Italian study of childhood leukaemia based on 120 cases with four controls per case, matched by age and gender, Crosignani et al (2004) estimated the annual mean concentration of benzene outside the home using a Gaussian diffusion model. This model uses traffic density (vehicles/day) on nearby main roads, distance between roads and residence, and information on vehicle emissions and weather conditions to estimate benzene concentration. Compared to children whose homes were not exposed to road traffic emissions (<0.1 $\mu g/m^3$ of benzene as estimated by the model), the risk of childhood leukaemia was significantly higher (relative risk [RR] = 3.91; 95% CI = 1.36-11.27) for heavily exposed children (over 10 $\mu g/m^3$ estimated annual average). For the intermediate exposure group (0.1-10 $\mu g/m^3$) the relative risk was 1.51 (95% CI = 0.91-2.51).

In conclusion, although carcinogens are present in traffic emissions, there is little evidence that residential proximity to traffic is associated with a substantially increased cancer risk. Cancers have many causes and childhood cancers are particularly poorly understood. Although it seems unlikely that traffic pollution is associated with a substantially increased cancer risk in children, it is difficult to entirely discount an association with a slightly increased leukaemia risk.

A2.2.2.5 Adverse pregnancy outcomes

A number of studies have found associations between air pollution and premature birth and/or low birth weight (eg Rogers and Dunlop, 2006; Basu et al, 2004). A smaller number of studies have specifically examined pregnancy outcome in relation to exposure to traffic emission. Yang et al (2003) reported that the adjusted odds ratio was 1.30 (95% confidence interval = 1.03, 1.65) for delivery of preterm infants born to mothers who lived within 500 m of a major highway in Taiwan. Wilhellm and Ritz (2003) calculated odds ratios (ORs) and risk ratios (RRs) for being LBW and/or preterm per quintile of traffic-related air pollution using a distance-weighted traffic density (DWTD) measure. The clearest exposure-response pattern was observed for preterm birth, with an RR of 1.08 [95% CI, 1.01-1.15] for infants in the highest DWTD quintile. Although higher risks were observed for LBW infants, exposure-response relations were less consistent.

Overall, the results of published studies would suggest that residential proximity to traffic is associated with a small increased risk of adverse effects on pregnancy outcome, although there are many other influences on foetal and maternal health during pregnancy.

A2.2.2.6 Importance of nitrogen dioxide in the relationship between urban air pollution and health

Nitrogen dioxide (NO_2) is a well established marker of traffic pollution. There has been considerable debate as to whether effects attributed to NO_2 in epidemiological investigations of the health effects associated with urban air pollution are due to NO_2 itself or whether effects are actually caused by co-exposure to some unmeasured component of urban air pollution such as fine particles (Seaton and Dennekamp). The poor correlation between personal exposure and ambient concentrations and more specifically ambient concentrations measured at central locations, has greatly weakened the power of epidemiological studies to determine a specific relationship between ambient NO_2 and health (Searl, 2004).

Toxicological studies have shown effects in animals exposed to concentrations of NO_2 that are marginally higher than those found in ambient air during high pollution episodes. Serious adverse effects on the respiratory health of animals have only been reported at concentrations of NO_2 that are higher than those found in ambient air (Searl, 2004). The results of human volunteer experiments show that NO_2 has effects on lung function, airways responsiveness, respiratory symptoms and on the response of asthmatics to allergens but at concentrations that are slightly higher than those found in ambient air during high pollution episodes (Searl, 2004).

Epidemiological studies of the short-term effects of NO_2 in ambient suggest a small apparent effect on health that is independent of that of PM_{10} but do not exclude the possibility that the observed effects are partly due to some other unmeasured component of traffic pollution rather than gaseous NO_2 (Searl, 2004). The observation in a major European study that the slope of the concentration-response function linking PM_{10} to daily mortality gets steeper as concentrations of NO_2 increase might reflect an association between NO_2 and an increased proportion of traffic generated ultrafine particles in PM_{10} rather than being a direct effect of NO_2 in enhancing the effects of PM_{10}. The results of studies of the long term effects of exposure to NO_2 in indoor air or ambient air are not strongly suggestive of an adverse effect. Previously reported associations between NO_2 and respiratory symptoms reflect a relationship with gas cooking rather than NO_2.

Overall, it seems likely that during high pollution events, NO_2 has a small adverse effect on health that is independent of that of particles. It seems plausible that exposure to NO_2 may slightly enhance the response to particles through its contribution to oxidative stress. It is impossible, however, to determine how much of the apparent effect of NO_2 in epidemiological studies is actually due to exposure to some other unmeasured component of traffic pollution (Searl, 2004).

A2.2.2.7 Implications

There is a substantial quantity of evidence to link exposure to traffic pollution to a range of adverse health effects such that the implementation of the low emission zone would be expected to have a beneficial effect on health. Expected benefits would include an improvement in children's respiratory health and in the cardiovascular and respiratory health of adults. There is a general consensus that fine particles are the most damaging component of air pollution and little evidence that the introduction of measures that would specifically target NO_2 rather than particles would have a substantial benefit.

A2.2.3 HEALTH IMPACTS OF AIR QUALITY IMPROVEMENTS

A number of studies have established that reduced levels of air pollution are associated with an improvement in health. Burr et al (2004) identified a town in North Wales where certain streets air pollution associated with heavy road traffic was likely to reduce following the construction of a by-pass. A respiratory survey was conducted among the residents, together with the residents of nearby uncongested streets, at baseline and again a year after the by-pass opened. Initial concentrations of PM_{10} and $PM_{2.5}$ were substantially higher in the congested than in the uncongested streets. When the by-pass opened, the volume of heavy goods traffic fell by nearly 50%. PM_{10} decreased by 23% (8.0 $\mu g/m^3$) in the congested streets and by 29% (3.4 $\mu g/m^3$) in the uncongested streets, with similar proportionate falls in $PM_{2.5}$.

There were no clear or consistent initial differences between the residents of the two areas in terms of symptoms or peak flow variability. Repeat questionnaires were obtained from 165 and 283 subjects in the congested and uncongested areas respectively, and showed a tendency for most symptoms to improve in both areas. For chest symptoms, the improvement tended to be greater in the uncongested area, although the difference between the areas was not statistically significant. Against a background incidence of wheeze of about 33%, there was a reduction in prevalence of 0.6% in congested streets and about 7% in uncongested streets. Rhinitis and rhinoconjunctivitis tended to improve to a greater extent in the congested streets. Against background prevalences of about 20 and 40% respectively, there was a reduction in prevalence of about 11 and 7% in congested streets and of about 6 and 0.4% in uncongested streets. There was no significant difference in peak flow before and after the by pass opened.

Following the finding of a positive association between health care utilization and prevalence of asthma, and commercial traffic at a U.S.-Canada border crossing, Lwebuga-Mukasa et al (2003) examined the effect of reduced traffic volumes on health care utilization for respiratory illnesses. Following September 11, 2001, there was a 50% drop in total traffic at the Peace Bridge border crossing point between Buffalo, New York and Fort Erie, Ontario, Canada. Comparison of the 3-month periods in 2000 and 2001 (August, September, and October) showed a 50% drop in total traffic following Labor Day and September 11, 2001. There was a corresponding decrease in health care utilization for respiratory diseases which fell to about 75% of the level reported during the same period, the previous year. The reduction in upper respiratory illness appears to have occurred almost immediately following the reduction in traffic levels whereas the effects on lower respiratory illness was approximately two weeks later.

Bayer-Oglesby et al (2003) studied 9,591 Swiss children between 1992 and 2001 in nine communities where a modest decline in air pollution had occurred. Following adjustment for socio-economic, health-related, and indoor factors, declining PM_{10} was associated in logistic regression models with declining prevalence of chronic cough [odds ratio (OR) per 10 $\mu g/m^3$ decline = 0.65, 95% CI, 0.54-0.79], bronchitis (OR = 0.66; 95% CI, 0.55-0.80), common cold (OR = 0.78; 95% CI, 0.68-0.89), nocturnal dry cough (OR = 0.70; 95% CI, 0.60-0.83), and conjunctivitis symptoms (OR = 0.81; 95% CI, 0.70-0.95). Overall, their results suggest that a drop in concentrations of PM_{10} of about 10 $\mu g/m^3$ would be expected to lead a reduction of about 30% in the prevalence of respiratory symptoms in children. Changes in prevalence of sneezing during pollen season, asthma, and hay fever were not associated with the PM_{10} reduction.

Heinrich (2003) reviewed the effects of the decline of combustion-derived emissions of traditional air pollutants such as sulphur dioxide (SO2) and total suspended particles (TSP) in eastern Germany shortly after German reunification in 1990. Two repeated surveys of nonallergic respiratory illness showed that the crude prevalence of respiratory illness such as lifetime bronchitis, otitis media, tonsillitis, frequent colds, and frequent cough decreased during the 1990s in children in eastern Germany. Heinrich et al (2000) described the change in the prevalence of nonasthmatic respiratory symptoms and diseases in children living in three areas of East Germany during a phase of strong improvement in ambient air quality.

Groups of 2,470 and 2,814 school children between 5 and 14 yr, respectively, participated in two regional cross-sectional studies in 1992-1993 and 1995-1996. In the three areas (Hettstedt, Bitterfeld, and Zerbst) examined, the annual mean TSP decreased from 65, 48, and 44 $\mu g/m^3$, respectively, in 1993 to 43, 39, and 36 $\mu g/m^3$ in 1995. In the same time interval, the crude prevalence of bronchitis in the three respective areas decreased from 62%, 52%, and 50% to 47%, 40%, and 39%. During the 3-yr period between the two regional studies, prevalence decreased significantly for bronchitis (odds ratio [OR]: 0.55; CI: 0.49 to 0.62), for otitis media (OR: 0.83; CI: 0.73 to 0.96), for frequent colds (OR: 0.74; CI: 0.64 to 0.86), and for febrile infections (OR: 0.76; CI: 0.66 to 0.88) after adjustment for several potential predictors. In general terms, the reduction in respiratory symptoms appears to have been of a consistent scale to that observed in the Autrian study. Sugiri et al (2006) showed that reduced levels of total suspended particulate in eastern Germany were associated with better measures of lung function in 6 year old children, but that this effect was diminished in children living near busy roads.

Clancy et al (2002) compared the concentrations of air pollution and directly-standardised non-trauma, respiratory, and cardiovascular death rates for 72 months before and after the ban of coal sales in Dublin. Average black smoke concentrations (a proxy for particles) in Dublin declined by 35.6 $\mu g/m^3$ (70%) from an annual mean of 50.2 to 14.6 $\mu g/m^3$. after the ban on coal sales. Adjusted non-trauma death rates decreased by 5.7% (95% CI 4-7, $p<0.0001$), respiratory deaths by 15.5% (12-19, $p<0.0001$), and cardiovascular deaths by 10.3% (8-13, $p<0.0001$). The fall in respiratory and cardiovascular standardised death rates coincided with the ban on coal sales. About 116 fewer respiratory deaths and 243 fewer cardiovascular deaths were seen per year in Dublin after the ban with the benefits being greater than would have been predicted from the results of daily mortality elsewhere.

In an investigation of the effects of long term exposure to $PM_{2.5}$ in six US cities, Laden et al (2006) found that the reduction in levels of particle exposure between the early 1980s and the 1990s were associated with a decrease in mortality rate, after allowance for the general increase in life expectancy in the US over the same period. The cities with the greatest reductions in $PM_{2.5}$ also showed the greatest fall in mortality rates. The reduction in risk was greatest for cardiovascular and respiratory disease and there was a much smaller reduction in lung cancer risk. The smaller effect for lung cancer was attributed to its longer latency and less reversibility than cardiovascular or respiratory disease.

In a study of an area in Jerusalem adjacent to a municipal dump where residents were exposed to increased levels of dust and diesel fume, closure of the dump was associated with a reduction of about a third in the proportion of local residents experiencing respiratory symptoms such as cough, phlegm and shortness of breath (Gabrovska et al, 2004).

Wong et al (1998) examined the impact on children's respiratory health of a government air quality intervention that restricted the sulphur content of fuels to 0.5% from July 1990 onwards. Changes in airway hyperreactivity of non-asthmatic and non-wheezing, primary years 4-6 school children (aged 9-12 years) living in a polluted district were compared with those in a less polluted district. Measurements made before the intervention and one and two years afterwards, showed that bronchial hyper-responsiveness declined in both the polluted and the less polluted district with a greater decline in the polluted district.

Studies undertaken elsewhere have confirmed that real health benefits are observed following the implementation of measures intended to improve air quality. The Dublin study appears to demonstrate that air quality improvements are associated with a very rapid improvement in general health as evidenced by mortality risk. Similarly the results of the Canadian study suggest that reduced exposure to traffic pollution leads to an immediate improvement in respiratory health at a population level. The North Wales by pass study demonstrated that reduced exposure to traffic emissions was associated with a small improvement in respiratory health, against a relatively high background prevalence of respiratory symptoms. The proportionate change in respiratory health symptoms reporting was small relative to the proportionate change in concentrations of PM_{10}.

Overall results of studies undertaken elsewhere suggest that implementation of the LEZ would be expected to confer an immediate benefit and lasting benefit on respiratory and cardiovascular health, but the influence of the LEZ on respiratory health may be small in comparison to other factors. This is because the change in air quality that would be expected to arise as a result of implementation of the LEZ is small compared with the changes that were investigated in published studies.

A2.2.4 GROUPS SUSCEPTIBLE TO AIR POLLUTION

A2.2.4.1 Interaction between deprivation and air pollution

There is a well established association between deprivation and ill health giving rise to lower life expectancies and greater morbidity in deprived areas. This includes risks of cardiovascular and serious respiratory disease. For example, a recent study in Liverpool found that asthma prevalence was related to socio-economic deprivation as well as being associated with obesity (Rizwan et al, 2004). Higher background rates of ill-health mean that the impacts of any proportionate increment in risk arising from exposure to air pollution in deprived areas is relatively greater than in better off areas. In addition there is increasing evidence that there is a greater proportionate increase in risk associated with a given increment in air pollution in deprived groups than in socially more advantaged groups.

In a study of participants aged 16-79 in the Health Survey for England 1995, 1996, and 1997, Wheeler and Ben-Shlomo (2005) found that social class and poor air quality were independently associated with decreased lung function but not asthma prevalence, after adjustment for a number of potential confounders. Social class effects were not attenuated by adjustment for air quality. In men, a differential effect of air pollution on lung function was found, with its effect in social classes III to V about double that in social classes I and II, which are higher socio-economic classes; a similar effect was not seen for women.

A recent Italian study found that the increase in daily mortality associated with PM_{10} was more pronounced among persons with lower income and socio-economic status (1.9% and 1.4% per 10 $\mu g/m^3$, respectively) compared to those in the upper income and socio-economic status levels (0.0% and 0.1%, respectively) with a mean effect of 1.1% increase, 95%CI = 0.7-1.6%, per 10 $\mu g/m^3$). Zanobetti and Schwartz analyzed total mortality in the four largest US cities with daily measurements of PM_{10}. They found evidence that effects were greater in women than men but little evidence that social factors or race had an important impact on PM_{10} effects.

In a Canadian study, Finkelstein et al (2003) found that mean pollutant levels tended to be higher in lower-income neighbourhoods and both income and pollutant levels were associated with mortality differences. Compared with people in the most favourable category (higher incomes and lower particulate levels), those with all other income-particulate combinations had a higher risk of non-accidental death (lower incomes and higher particulate levels: relative risk [RR] 2.62, 95% CI 1.67-4.13; lower incomes and lower particulate levels: RR 1.82, 95% CI 1.30-2.55; higher incomes and higher particulate levels: RR 1.33, 95% CI 1.12-1.57). The relative risk was lower at older ages.

In another Canadian time series study, Villeneuve et al (2003) reported that there was some suggestion of increased risk of all-cause and cardiovascular mortality at lower levels of socio-economic status but the small number of deaths observed within each stratum of socio-economic status prevented definite conclusions being drawn. A more recent study of the association between daily cardiac hospitalizations and daily concentrations of gaseous air pollutants in ten large Canadian cities found that gender, community level of education or income did not affect the relationship between air pollution and cardiovascular health (Cakmak et al, 2006). In another Canadian study, low educational attainment and high manufacturing employment was found to significantly and positively modified the acute mortality effects of air pollution exposure (Jerret et al, 2004).

A2.2.4.2 Other vulnerable groups

In a Brazilian time series study, Gouveia and Fletcher (2000) found that the increase in mortality risks associated with air pollution were greater for older age groups. In a study of elderly patients in the US, Bateson and Schwartz (2004) reported a 1.14% (95% CI = 0.44% to 1.85%) increased risk of death per 10 $\mu g/m^3$ increase in ambient PM_{10} concentration. Persons with heart or lung disease-but no specific diagnosis of myocardial infarction, diabetes, congestive heart failure, chronic obstructive pulmonary disorder, or conduction disorders were at 0.74% (-0.29% to 1.79%) increased risk whereas those with a history of myocardial infarction had a 2.7-fold higher risk (CI = -2.1 to 7.4) and those with diabetes carried a two-fold higher risk (CI = -1.5 to 5.5).

In a US study of daily mortality from cardiovascular and respiratory causes, Zeka et al (2005) reported that age did not have a modifying effect on the effects on PM_{10} on age standardised mortality rates, although the relative impact of an increment in PM_{10} was greater in cities with older populations (that is with higher proportions older than 65 or 75 years in age) consistent with the elderly being more susceptible. They noted that Katsouyanni et al (2001) had reported a similar effect in a study of European cities.

Pre-existing disease may have an important modifying effect on daily mortality risks arising from air pollution exposure. For example, in a Chinese study, Kan et al (2004) established that diabetics are more likely to die on high pollution days than others.

In a small US panel study involving adults and children with asthma, Mar et al (2004) found that children appeared to be more susceptible to the effects of air pollution than adults with a relationship between airborne particles and respiratory symptoms being apparent in children but not adults.

A2.2.4.3 Implications

The poor, elderly, children and those with pre-existing illness may be most vulnerable to the adverse effects of air pollution and would therefore be the groups most likely to benefit from introduction of the LEZ. It is likely that some of the greatest improvements in air quality will be experienced in deprived communities that currently have above average levels of air pollution.

A2.3 Perceived environmental quality and health

A2.3.1 INTRODUCTION

There is growing evidence that people's health is influenced by their perception of their local environment and thus the implementation of the LEZ may bring a greater benefit as a result of the perceived improvement in air quality than that arising from the actual improvement in air quality. There has been some limited investigation of the health impacts arising from perceived exposure to air pollution that may of relevance to assessing the scale of impact. There are also a number of studies of the relationship between health and wider perceptions of environmental quality that may be relevant.

A2.2.2 PERCEPTION OF AIR QUALITY

People's perception of their exposure to air pollution is affected by a range of factors including the visibility of sources, odour nuisance, their respiratory health and media images. Those with poor respiratory health, living in areas of high traffic flow and without access to a car tend to have a greater perceived exposure to air pollution than other groups.

In cross-sectional study of 3402 households in England in a mixed rural and urban area adjacent to a large industrial complex, Hunter et al (2004) reported strong associations ($p < 0.01$) between perceived air pollution and the presence of a person in the home with respiratory symptoms, the belief that industrial pollution was harming their health, social class, living in rented accommodation and reporting noise from neighbours and other people's smoke. Smoking behaviour did not affect reporting.

In a comparative study undertaken at two different areas in London, Williams and Bird (2003) found that the public's perception of air quality was not a reliable indicator of the actual levels of air pollution in their area. The results also revealed that air pollution issues generated as a result of road traffic are of high importance in terms of people's quality of life when compared to other aspects of their quality of life. Residents in the urban area (Wood Green) were more disturbed by road traffic than residents in the suburban area (Wimbledon) and vehicle-derived fumes, dust and dirt caused more disturbance than other aspects of road traffic related nuisance.

Heinrich et al (2005) found that when parents of Dutch and German children were asked to rate their exposure to traffic pollution, their ratings were only weakly related to modelled exposures to air pollutants. Of the self reported low traffic exposed group, 71-73% in Munich and 45-47% in the Netherlands had low modelled exposure to these three air pollutants. Of the self assessed high exposed subgroups in Munich (15% of the total population) and the Netherlands (22% of the total population), only 22-33% and 30-32% respectively had high modelled exposure to the three air pollutants. The subjective assessments tend to overestimate the modelled estimates for $PM_{2.5}$ and NO_2 in both study areas.

In contrast in a study of Swedish adults, the prevalence of reported annoyance related to air pollution and traffic exhaust fumes was consistently correlated with the six-month mean nitrogen dioxide concentrations, although black smoke and sulphur dioxide had no significant effects. The frequency of reporting annoyance reactions was higher among people with asthma, women, and people with lack of access to a car (Forsberg et al 1997). A study undertaken in Texas found that perceptions of air quality in the study areas are not significantly correlated with air quality based on readings of air monitoring stations. Instead, perceptions appeared to be influenced by setting (urban vs. rural), state identification, access to information, and socioeconomic characteristics such as age, race, and political identification (Brody et al, 2004). In a study of London parents, parents with experience of asthma were found to have significantly less accurate (negatively biased) perceptions of local air quality (Stevens et al, 2004).

Health effects in relation to perceived air quality

Dalton (1999) demonstrated the importance of odour perception in symptom reporting by exposing volunteers to odours described as being good for health or harmful. Individuals given a harmful bias reported significantly more health symptoms following exposure and more intense odour and irritation during exposure than did those given a neutral or healthful bias. The overall pattern of results suggests that many of the health-related effects of exposure to odorants are mediated not by a direct agency of odours but by cognitive variables, such as mental models of the relationship between environmental odours and health.

In a questionnaire study conducted in the area of Ellesmere Port and Neston Borough Council, Hunter et al (2003) found that adult respiratory symptoms were associated with perception of industrial air pollution and neighbour noise in univariable but not multivariable analyses. In the multivariable model, symptoms were associated with number of people in the household who had ever smoked, exposure to traffic fume pollution, crowding and living in rented accommodation suggesting a complex relationship between actual levels of, social deprivation, socio-behavioural factors and people's perceptions about pollution.

In an Austrian study adult respondents in 13 small alpine communities with relatively low levels of air pollution felt annoyed by odorous traffic fumes (39.7%) or visible dust/soot (26.9%). Noise annoyance, rated impairment of life quality, protesting behaviour, noise- and odour-sensitivity was directly associated with perceived air quality, while age above 45 years, smoking, and social support was inversely associated with perceived air quality. Among the symptoms, feelings of fatigue / exhaustion / low mood / nervousness and irritation of the eyes and stomach aches showed a significant association with rated air quality. Children in the traffic exposed areas spend less time outdoors and reported perception of car fumes was significantly associated with recurrent colds, chronic bronchitis and an index of hyperreactive airways. Measured indices of pollution (traffic counts, NO_2) were not associated with any of the children's reported illnesses.

In a study of 2,744 adults resident in five neighbourhoods in Northeast England, Howel et al (2003) reported that there was relatively little variation in views about air pollution and health links between neighbourhoods. The greatest contrasts were found when comparing those living near or further from industry and between the two districts. Any differences were related more to awareness of illness in the neighbourhood thought to be affected by air pollution, rather than belief that a particular disease was linked to air pollution. Chronic illness status and age were sometimes found to be associated with perceptions of disease affected by air pollution, but gender and material deprivation were not central to differences in risk perceptions among the population studied.

In a London study of parents of children with asthma, many were unsure as to what factors initiate asthma, but the most frequently cited was traffic pollution; it was also considered important in the exacerbation of asthma.

There is some evidence that individual's perceptions of local air quality may influence their overall well being and that odour may play an important role in determining whether people's perceptions of air quality.

A2.3.3 OTHER STUDIES OF THE RELATIONSHIP BETWEEN (PERCEIVED) ENVIRONMENTAL QUALITY & HEALTH

Environmental quality is hard to define and in an urban environment, perception plays a major role in how individuals judge environmental quality. There is substantial evidence from UK studies that local area has a greater impact on health than individual socio-economic status, although socio-economic status at an area level has an important impact on how the local environment is perceived and on health.

In a study of 11-16 year olds in Wales, those who reported living with busy traffic and car parking were found to be less likely to have positive perceptions of the safety, friendliness, appearance, play facilities and helpfulness of the people in their local area (Mullan, 2003). This was independent of the effect of socio-economic circumstance and may give rise to a negative effect on sense of community identity, health and well-being. A Japanese study of over 5000 adults found that those whose bedrooms were located to an arterial road of other roads had lower health-related quality of life scores than those not living near any road. The adjusted mean scores of those living on arterial roads for "mental health" and "vitality" were significantly lower than those no near any road (Yamazaki et al, 2005).

Several studies have found an association between housing quality and health, although it possible that this is largely due to socio-economic effects. Chandola (2000) showed that income and housing tenure were associated with significant patterns of inequalities in mortality. In a study based on the death registers of a UK general practice (856 deaths), Beale et al (2002) found consistent and significant differences in death rates between Council Tax Valuation Band - above average for bands A and B residents; below average for other band residents. Female A and B residents had significantly raised risks of premature death.

In a Swiss study of 3,870 subjects aged 18-70yrs who had moved in 1997 (participation rate 55.7%), a gain in self rated health was most strongly predicted by an improved satisfaction with indicators related to the environmental housing quality (Kahlmeier et al, 2001). These included "location of building", "perceived air quality", the apartment itself, namely "suitability", "relationship with neighbours" and "noise from neighbours". The destination of moving and the main reason to move modified some of the associations with environmental indicators. Data from the Whitehall II study suggests that the demographic characteristics of residents, level of deprivation in the area, housing and neighbourhood quality and social integration were independently associated with health but did not fully explain differences between areas (Stafford et al, 2001). Area deprivation did not explain why lower status participants had poorer health.

An indirect impact of perceived poor environmental quality arising from excessive traffic may give rise to a reluctance to walk and cycle and may contribute to parents restricting the activities of their children limiting outdoor play and the freedom to walk or cycle round the city (THE PEP, 2004; WHO, 2000). The perception of environmental improvement may help in the promotion of walking and cycling with associated benefits for the health of those who participate (THE PEP, 2004).

A2.3.4 HEALTH BENEFITS ASSOCIATED WITH ENVIRONMENTAL IMPROVEMENTS

Specific studies of the impacts of urban regeneration or other neighbourhood improvement schemes have shown mixed outcomes. In a longitudinal, nationally representative survey of 8301 adults aged 16 years and older living in private households, there was modest evidence of clustering of poor general health within areas and stronger support for within household similarities in general health which increased over time (Sacker et al, 2006). There was greater evidence of clustering of limiting illness within areas but deprivation did not account for this to any great extent. Area differences in general health reduced as the economy improved but time trends in differences in limiting illness lagged behind the timing of economic recovery.

Thomson et al (2006) reviewed the impact on health and key socio-economic determinants of health and health inequalities reported in 19 evaluations of national UK regeneration programmes. Three evaluations reported health impacts; in one evaluation three of four measures of self reported health deteriorated, typically by around 4%. Two other evaluations reported overall reductions in mortality rates. Most socio-economic outcomes assessed showed an overall improvement after regeneration investment; however, the effect size was often similar to national trends. In addition, some evaluations reported adverse impacts. Overall, there was little evidence of the impact of national urban regeneration investment on socio-economic or health outcomes.

In a longitudinal study with 22-month follow-up in a Single Regeneration Budget area, and matched control area in South Manchester, Huxley et al (2004) found no improvement in mental health outcome in the index and control areas, health satisfaction declined slightly in the index compared to the control area and GP use was unchanged. It was concluded that the urban regeneration initiative may have had little impact because it failed to address the concerns of local residents and to remove restrictions on opportunity. In contrast, Boyle et al (2004) found that area changes in socio-economic deprivation did impact on the health and well being of long term residents of non-deprived households with the impacts on morbidity being greater than those on mortality.

In terms of specific intervention measures, several studies have investigated the health benefits of traffic calming schemes, mostly in relation to accidents (see below). In a more general evaluation of the benefits of a traffic calming scheme built into a main road in Scotland, Morrison et al (2004) reported that the scheme led to an increase in pedestrian activity and a significant improvement in physical but not mental health. There was a reduction in traffic-related nuisance but other local nuisances were reported to increase. A limited response to the questionnaire survey, however, may limit the validity of the study findings.

Conclusions

Although neighbourhood quality is linked to health, it is unclear if improving quality improves health, unless underlying health determinants such as employment are improved. The LEZ is unlikely to change neighbourhood quality – it has a beneficial effect on one parameter affecting quality (air pollution).

A2.3.5 IMPLICATIONS

A perception of improved environmental quality following the introduction of the LEZ could have a small beneficial effect on well being leading to slightly improved health status in some individuals. The perceived improvement in environmental quality might also encourage greater participation in walking and cycling giving rise to improved health in those who participate (though as the LEZ does not change traffic numbers or speeds, these latter effects may be very low).

It is difficult to predict the relative importance of this effect on health as there are few relevant published data. Provision of information on the air quality and health benefits of the LEZ to general community may play an important role in giving rise to health improvements.

A2.4 Impacts of other environmental impacts and socio-economic changes arising from implementation of the LEZ

A2.4.1 EFFECTS OF NOISE EXPOSURE

High levels of exposure to noise are associated with annoyance (an associated adverse effects on mental well being), sleep disturbance, increased risks of cardiovascular illness and effects on children's learning and behaviour. The WHO (2000a) considered that transport noise was an underestimated cause of stress and illness and identified children, the hearing impaired, the elderly and those who are ill as being at particular risk. The impacts of implementation of the LEZ on average noise exposure in London will be tiny, but are unlikely to be evenly distributed, such that the greatest benefits are likely to arise in close proximity to the most heavily trafficked streets. Children in school may be particularly vulnerable to noise, and thus some benefits may be expected where schools are located immediately alongside busy roads.

In a study of 2,010 children aged 9-10 years from 89 schools around Amsterdam Schiphol, Madrid Barajas, and London Heathrow airports, Clark et al (2006) found that aircraft noise exposure at school was linearly associated with impaired reading comprehension but road traffic noise exposure at school was not associated with reading comprehension in either the absence or the presence of aircraft noise.

In an earlier report from the same study, Stansfeld et al (2005) identified linear exposure-effect associations between exposure to chronic aircraft noise and impairment of reading comprehension and recognition memory, and a non-linear association with annoyance maintained after adjustment for mother's education, socio-economic status, longstanding illness, and extent of classroom insulation against noise. Exposure to road traffic noise was linearly associated with increases in episodic memory but also with annoyance. Neither aircraft noise nor traffic noise affected sustained attention, self-reported health, or overall mental health.

Evans et al (2001) examined indices of stress among children living under 50 dB or above 60 dB (A-weighted, day-night average sound levels) in small towns and villages in Austria. The major noise sources were local road and rail traffic. The two samples were comparable in parental education, housing characteristics, family size, marital status, and body mass index, and index of body fat. Children in the noisier areas had elevated resting systolic blood pressure and increased levels of cortisol (a biochemical marker of stress) in overnight (8 hour) urine samples. The children from noisier neighbourhoods also evidenced elevated heart rate reactivity to a discrete stressor (reading test) in the laboratory and rated themselves higher in perceived stress symptoms on a standardized index. Furthermore girls, but not boys, showed reduced motivation in a standardized behavioural protocol.

In a German study, Ising et al (2004) reported that children exposed to high levels of noise at home (L(night, 8h) =54-70dB(A)) had significantly increased morning saliva cortisol concentrations in comparison to other children, indicating an activation of the hypothalamus-pituitary-adrenal (HPA) axis. They also found evidence that high exposure to traffic noise, especially at night time, may be associated with aggravation of bronchitis in children.

A small reduction in noise in the immediate vicinity of the most heavily trafficked routes in the LEZ may be associated with a marginal health benefit for local residents. There are some vulnerable groups who could see proportionally greater benefits, e.g.. children attending schools sited immediately beside busy thoroughfares, deprived communities living at roadside, but the noise reduction is expected to be small (only just perceptible) and would not give rise to a measurable health benefit.

A2.4.2 EFFECTS OF SOCIO-ECONOMIC CHANGES ON HEALTH

A2.4.2.1 Introduction

The socio-economic impacts of the LEZ are expected to be mixed. A small number of individuals may lose employment if small business are unable to afford to upgrade their vehicles to conform with the LEZ. Businesses in already deprived areas may be most at risk. In contrast, other businesses may benefit from the increase in turnover associated with the supply of compliant vehicles or retrofitting of older vehicles.

There is a vast literature on the socio-economic determinants of health including a large number of studies conducted in the UK. Only a very preliminary review of this literature has been made in order to gain an impression of the potential magnitude of any impacts on health arising from socio-economic changes induced by the LEZ.

A2.4.2.2 Relationship between social economic status and health

A number of studies have reported associations between socio-economic status and health. Saxena et al (2006) examined age-standardized hospital admission rates for asthma, diabetes, heart failure, hypertension and chronic obstructive pulmonary disease across 31 primary care trusts in London (population 7 million) and found a significant association between higher admission rates and measures of underlying ill health and material deprivation but not quantitative measures of primary care service provision.

Data from the Health and Lifestyle Survey (1984-1985), a national sample survey of UK adults, aged 18 upwards suggested an approximately linear relationship between the logarithm of household equivalised income and various indices of morbidity: height, waist-hip ratio, respiratory function, malaise, limiting longterm illness (Ecob and Smith, 1999). The relationship broke down at very high and low incomes suggesting that, although increasing income is associated with better health, there are diminishing returns at higher levels of income. In a small area study, Janghorbani et al (2006) found coronary heart disease (CHD) mortality and hospital admission in Plymouth increased with Townsend deprivation score in all ages and gender groups. The age-adjusted deprivation-associated excess CHD hospital admission was 15.4% in men and 27.9% in women higher for most compared to the least deprived group. The age-adjusted deprivation-associated excess CHD mortality was 31.5% and 18.9% for men and women, respectively. The most deprived areas showed the highest mortality and hospital admission risk.

A study of angina in Scotland found an increase in prevalence with increasing socio-economic deprivation from 18/1000 in the least deprived category to 31/1000 in the most deprived group ($p < 0.001$ for trend; Murphy et al, 2006). A study of social inequalities in psychological status in the 1958 British birth cohort, followed over three decades found an approximately threefold increase in risk of psychological distress in social classes IVandV compared with IandII (Power et al, 2002). Adult life factors varied, with stronger effects for work factors (job strain and insecurity) for men and qualifications on leaving school, early child-bearing and financial hardship for women.

In a study based on the Retirement and Retirement Plans Survey and follow-up, a two-wave study of persons aged 55-69 in 1988/9, Grundy and Holt (2000) found that self rated health and disability status at baseline and at follow up were associated with socio-economic and geographic variables, such as proportion of adult life spent unemployed and residence outside the Southeast of England; demographic factors, such as early age at marriage and high parity; and experience of adverse events, such as the death of a child and being dismissed from work. In a study of the relationship of ethnicity, social deprivation (Underprivileged area, UPA-score), social class V, unemployment and overcrowding on age- and sex-standardized mortality ratio (SMR), Sundquist et al (1996) found a significant association between UPA-score and SMR. Increased mortality risks were associated with being unskilled, unemployed and living in overcrowded households whereas origin from New Commonwealth countries or Pakistan was associated with a reduced mortality risk.

A number of studies have demonstrated a relationship between area level socio-economic status and health. Stafford and Marmot (2003) reported whereas individual deprivation was not associated with adverse health effects in affluent areas, substantial adverse effects arise in deprived areas, possibly because of the lower collective resources of the neighbourhood. Craig (2005) reported a significant positive association between income inequality and self-assessed health across local authorities in Scotland, even after adjusting for individual-level socio-economic status. In a study of common mental disorders in relation to ward-level socio-economic deprivation measured using the Carstairs index, Weich et al (2005) reported that 1% of total variance, in onset and maintenance of common mental disorders occurred at ward level but 12% of variance, a statistically significant difference, was found at household level. Chandola and Jenkinson (2000) found significant social class differences as measured by the UK National Statistics Socio-Economic Classification (NS-SEC), in the physical and mental health summary scores after controlling for age. When lifestyle, housing and neighbourhood conditions were controlled for, however, these differences reduce to non-significance suggesting that social class differences in housing, neighbourhood and lifestyle factors may have a large role in understanding class differences in health.

Other studies have found evidence that neighbourhood characteristics may have an important influence on health, but less evidence of a specific link with deprivation. For example, in a cross sectional study of a sample of people from the Health Survey for England and the Scottish Health Survey, Cummins et al (2005) found that fair to very bad self rated health was significantly associated with six neighbourhood attributes: poor physical quality residential environment, left wing political climate, low political engagement, high unemployment, lower access to private transport, and lower transport wealth. Associations were independent of sex, age, social class, and economic activity but odds ratios were larger for non-employed residents than for employed residents. Self rated health was not significantly associated with five other neighbourhood measures: public recreation facilities, crime, health service provision, access to food shops, or access to banks and buildings societies.

The collective results of these studies suggest that neighbourhood socio-economic status is linked to both physical and mental health such that improvements in socio-economic status at a neighbourhood level would be expected to be beneficial to health. There is also evidence that socio-economic status at the individual level may also have an important influence on health.

A2.4.2.3 Role of employment status

Employment status has an important influence on health and well being. Bartley et al (2004) reported large differences in the risk of limiting illness according to occupational social class, with men and women in the least favourable employment conditions nearly four times more likely to become ill than those in the most favourable. Unemployment and economic inactivity had a powerful effect on illness incidence. Limiting illness was not a permanent state for most participants in the study and the likelihood of recovery was greatest for those who returned to employment. In a study of 7726 UK adults aged 16-75 living in private households, Weich and Lewis (1998) found that poverty and unemployment were associated with increased risks of mental illness. Unemployment increased the duration of episodes of common mental disorders but not the likelihood of their onset.

Drawing upon data from the 1992 British Household Panel Study, Theodossiou (1998) found that after controlling for a number of individual characteristics, unemployed individuals suffered significantly higher odds of experiencing a marked rise in anxiety, depression and loss of confidence and a reduction in self-esteem and the level of general happiness even compared with individuals in low-paid employment. Using data from the first eight waves of the British Household Panel Survey, Andres (2004) confirmed that mental health scores were significantly related to job status, age, marital status and self-assessed health status but found no evidence that income impacts on self-reported mental health.

Using data on 24,975 respondents to the Welsh Health Survey 1998 aged 17-74 years, Fone and Dunstan (2006) found that mental health was significantly associated with the Townsend score after adjusting for composition, and this effect was strongest in respondents who were economically inactive. Economic inactivity at the electoral division level also impacted on mental health, suggesting that the places in which people live affect their mental health. In a study of social inequalities in minor psychiatric morbidity in 8091 original adult respondents of working age during 1991-1998 from the British Household Panel Survey (BHPS), Wiggins et al (2004) found that among employed men and women in good health, social class, status, or income had little impact on mental wellbeing but psychiatric morbidity increased with increasing disadvantage among the economically inactive. Among the unemployed, a "reverse" gradient was found: the impact of unemployment on minor psychiatric morbidity was higher for those who were previously in a more advantaged social class position. In a study of the self-rated health of the long-term unemployed based on data on 25.6 million adults from the UK 2001 Census, Whitehead et al (2005) found that the health of the long-term unemployed was better in high unemployment regions, and conversely, worse where the local labour market was traditionally stronger. This is the reverse of the regional pattern found, for different social classes and for those who have never worked.

A2.4.2.4 Effects of changes in employment status

Changes in employment status may have a substantial impact on the health of some individuals. Thomas et al (2005) studied 13,359 employment transitions from 5,092 people aged 16-74 years in the British household panel survey from 1991 to 1998. Transitions from paid employment to either unemployment or long term sick leave were associated with increased psychological distress for both men and women. Transitions from these roles to formal employment resulted in an improvement in mental health.

Whereas being unemployed appears to be associated with an adverse risk to health, the effects of changing job are less clear, Metcalfe et al (2003) conducted a cross-sectional study of the effects of frequent job changes that was based on data collected in the early 1970s from 5399 men and 945 women in paid work, recruited from 27 workplaces in the west of Scotland. Those individuals who reported having experienced frequent job change were more likely to smoke, consume greater amounts of alcohol, and perhaps to exercise less. Similar findings were observed in both males and females, and for different age and socio-economic groups. There was no evidence that this association was due to higher levels of psychosocial stress, and the expected consequences for health were not observed.

A2.4.2.5 Implications

Overall, it would appear that any loss of employment arising as a result of business closures following the introduction of the LEZ would be associated with an increased risk of mental or physical illness in the newly unemployed.

A2.4.3 ROAD TRAFFIC ACCIDENTS – INFLUENCES ON RISK OF INJURY

The results of several studies have suggested that the risks of injury in a road traffic accident increase with increasing deprivation. In a study undertaken in North Lanarkshire, Scotland, Chichester et al (1998) reported an apparent positive association between road traffic accidents and deprivation that was significant after controlling for gender, victim role, purpose of journey and age, except for drivers 60 and over. Silversides et al (2005) found an association between deprivation and increased risk of injury in road traffic accidents in a study of children in Belfast. In a study of the epidemiology of femoral fractures in children in the West Midlands, Bridgman et al (2004) reported a 43% decrease in those caused by traffic accidents between the years 1991-2 to 2001-2. Traffic accidents were responsible for 26% of fractures varying from 55% in ten-year-old to 2% in one-year-old children. Twice as many fractures were seen in May to August than in January and the rates of fractures were associated with deprivation for all age-gender groups.

Hewson (2004) investigated accident rates in Devon and found an association between deprivation and increasing casualty involvement of child pedestrians. It appeared that the casualty rate may be more closely associated with deprivation measures of the ward in which the collision occurred than with the deprivation measures of the home address of the child. In a Canadian study, Joly et al (1989) found that the risks of accident for child bicyclists increased in areas of high population density, fast and dense vehicular traffic, and the absence of parks. Risks were higher for boys than girls and for children of lower socio-economic status. Accidents usually take place on two-way streets, on straight stretches far from traffic lights, on dry pavement, during clear weather when the visibility is good and often failure to obey traffic regulations was involved.

Jones et al (2005) established that area wide traffic calming in two UK cities led to a reduction in child pedestrian injuries with the greatest benefit arising in the most deprived areas, although this may partly reflect an increased number of measures in these areas. In the most deprived quartiles of the two cities injury rates for 9-12 year olds dropped from 9.42 to 5.07/1000 and from 8.02 to 7.46 over an 8 year period.

In addition to the direct risk of injury in traffic accidents, children are also at an indirect risk of decreased mobility and increased social isolation if a perceived traffic hazard leads to parents restricting children's activities to reduce the apparent risk of traffic injuries (WHO, 2000a). Similarly others in the community, such as the elderly or disabled, may be discouraged from making journeys on foot because of a perceived road traffic hazard. This may contribute to restricting the mobility and independence of these individuals giving rise to social isolation.

From the limited evidence available, it would appear that any improvement in road safety arising from implementation of the LEZ (as a result of the reduction in average vehicle age), would primarily benefit vehicle drivers, and possibly (as a group which has dis-proportionately high representation in accidents) children from deprived communities. An additional benefit could accrue if the introduction of the LEZ leads to the perception of improved road safety giving rise to increased mobility among children or others who are currently deterred from travelling by certain modes – though this seems unlikely given the scale of the changes – and the fact that safety perceptions are more likely to be driven by the number of vehicles and their speed.

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APPENDIX 3 - Distributional analysis of air quality health impacts

Contents

Proportion of Borough population in NO_2 exceedence areas (pre-LEZ), and reduction in exceedence populations post LEZ implementation	A3.1
Proportion of Borough population in PM_{10} exceedence areas (pre-LEZ), and reduction in exceedence populations post LEZ implementation	A3.2
Proportion of Borough population in PM_{10} exceedence areas (pre-LEZ) (as measured by more than 10 exceedence days on an annual basis), and reduction in exceedence populations post LEZ implementation	A3.3
Reduction in number of RADs in each year of LEZ scheme implementation (normalised by Borough population)	A3.4
Reduction in number of RADs in each year of LEZ scheme implementation	A3.5

Proportion of Borough population in NO_2 exceedence areas (pre-LEZ), and reduction in exceedence populations post LEZ implementation

Borough	2008			2010			2012		
	% popn exc. 40 ug/m3	Popn exc. 40 ug/m3	% reduction in exc. popn	% popn exc. 40 ug/m3	Popn exc. 40 ug/m3	% reduction in exc. popn	% popn exc. 40 ug/m3	Popn exc. 40 ug/m3	% reduction in exc. popn
Barking and Dagenham	1.2%	2,116	18.7%	0.3%	522	8.4%	0.2%	412	36.2%
Barnet	5.5%	18,025	10.2%	2.2%	7,342	10.5%	1.8%	5,920	27.4%
Bexley	1.5%	3,355	10.5%	0.4%	925	8.4%	0.3%	665	68.0%
Brent	10.4%	28,610	10.7%	3.4%	9,489	7.3%	2.7%	7,499	29.5%
Bromley	0.3%	829	17.4%	0.1%	175	6.8%	0.1%	164	25.4%
Camden	53.5%	110,124	7.3%	28.4%	59,549	5.7%	24.2%	51,139	26.8%
City of London	100.0%	7,448	0.0%	70.7%	5,355	7.6%	61.6%	4,715	22.3%
Croydon	4.4%	15,028	10.1%	1.4%	4,852	16.3%	1.0%	3,520	37.5%
Ealing	11.7%	36,500	7.8%	6.0%	19,089	5.1%	5.2%	16,808	16.3%
Enfield	3.7%	10,654	10.0%	1.9%	5,471	5.4%	1.6%	4,780	23.3%
Greenwich	6.8%	15,161	10.3%	2.9%	6,550	6.9%	2.4%	5,607	29.9%
Hackney	23.3%	49,221	11.6%	9.6%	20,525	11.0%	7.5%	16,324	38.1%
Hammersmith and Fulham	32.2%	55,372	8.7%	11.7%	20,449	9.6%	9.9%	17,398	21.8%
Haringey	8.4%	18,909	11.5%	2.9%	6,529	10.0%	1.9%	4,426	46.8%
Harrow	0.4%	911	19.0%	0.0%	101	14.2%	0.0%	85	0.0%
Havering	0.5%	1,137	12.5%	0.2%	525	4.6%	0.2%	396	24.4%
Hillingdon	3.3%	8,376	8.9%	1.7%	4,423	4.2%	1.6%	4,056	16.4%
Hounslow	5.3%	11,746	10.8%	2.0%	4,549	7.3%	1.7%	3,825	22.0%
Islington	50.7%	92,775	9.5%	17.9%	33,335	8.0%	14.6%	27,378	31.1%
Kensington and Chelsea	89.9%	148,648	4.9%	40.5%	68,079	6.7%	34.5%	58,517	18.0%
Kingston upon Thames	2.4%	3,696	5.8%	0.7%	1,126	7.5%	0.6%	959	33.1%
Lambeth	30.7%	85,111	12.1%	13.4%	37,673	7.1%	11.0%	31,137	29.0%
Lewisham	9.6%	24,740	10.1%	4.1%	10,828	10.5%	3.2%	8,606	30.8%
Merton	6.5%	12,753	13.5%	2.3%	4,504	12.1%	1.8%	3,708	33.2%
Newham	10.3%	26,197	12.2%	3.5%	9,142	12.4%	2.4%	6,127	42.2%
Redbridge	4.3%	10,777	10.6%	1.6%	4,126	12.5%	1.3%	3,265	24.8%
Richmond upon Thames	2.4%	4,329	9.1%	0.4%	643	28.0%	0.2%	391	43.9%
Southwark	35.3%	89,936	9.0%	16.3%	42,240	7.5%	13.3%	34,859	26.2%
Sutton	0.5%	947	31.5%	0.0%	56	21.3%	0.0%	45	51.1%
Tower Hamlets	23.4%	47,668	12.3%	9.3%	19,194	8.3%	7.7%	16,047	23.9%
Waltham Forest	20.6%	46,832	8.4%	9.3%	21,556	8.5%	7.8%	18,237	30.6%
Wandsworth	25.2%	68,307	11.1%	8.3%	22,932	8.9%	7.1%	19,607	28.6%
Westminster	93.4%	176,042	2.2%	56.1%	107,433	5.3%	48.8%	94,562	18.0%

Source: Estimates based on concentration data provided by ERG, LEZ Phase 5 modelling (2006)

Proportion of Borough population in PM_{10} exceedence areas (pre-LEZ), and reduction in exceedence populations post LEZ implementation

Borough	Total population	2008			2010			2012		
		% popn exc. 23 ug/m3	Popn exc. 23 ug/m3	% reduction in exc. popn	% popn exc. 23 ug/m3	Popn exc. 23 ug/m3	% reduction in exc. popn	% popn exc. 23 ug/m3	Popn exc. 23 ug/m3	% reduction in exc. popn
Barking and Dagenham	163,932	1.6%	2,705	10.8%	0.5%	811	8.6%	0.2%	379	27.7%
Barnet	314,506	4.3%	13,925	5.1%	1.9%	6,174	5.1%	1.3%	4,528	13.4%
Bexley	218,316	1.6%	3,652	7.7%	0.3%	777	10.5%	0.1%	328	26.9%
Brent	263,507	4.4%	11,938	8.7%	1.1%	3,150	5.4%	0.7%	1,921	17.2%
Bromley	295,544	0.5%	1,646	3.7%	0.1%	193	21.1%	0.0%	48	37.1%
Camden	198,038	20.6%	42,512	5.4%	5.9%	12,261	10.0%	3.4%	7,178	17.2%
City of London	7,162	49.8%	3,712	4.0%	19.5%	1,476	2.5%	14.0%	1,074	3.0%
Croydon	330,562	3.1%	10,659	9.7%	0.5%	1,635	11.4%	0.2%	674	30.8%
Ealing	300,975	6.9%	21,640	4.8%	1.9%	6,092	10.0%	0.8%	2,700	17.4%
Enfield	273,530	4.2%	12,036	6.6%	2.1%	6,038	5.1%	1.5%	4,317	15.1%
Greenwich	214,412	4.8%	10,794	5.9%	1.8%	4,042	6.5%	1.1%	2,586	17.6%
Hackney	202,832	7.4%	15,622	9.7%	1.4%	3,030	10.0%	0.8%	1,737	20.3%
Hammersmith and Fulham	165,156	10.5%	17,988	6.5%	3.6%	6,235	13.7%	2.1%	3,789	9.5%
Haringey	216,498	4.1%	9,257	8.3%	0.7%	1,587	11.8%	0.2%	454	24.2%
Harrow	206,822	0.8%	1,724	12.3%	0.1%	118	0.0%	0.0%	52	25.8%
Havering	224,243	0.9%	2,124	6.6%	0.2%	533	5.5%	0.1%	246	43.5%
Hillingdon	243,065	2.5%	6,199	5.9%	0.6%	1,621	10.6%	0.3%	793	24.6%
Hounslow	212,340	5.6%	12,328	5.4%	2.0%	4,456	3.3%	1.3%	2,984	10.5%
Islington	175,792	11.3%	20,700	7.0%	3.0%	5,522	7.6%	1.6%	3,073	35.3%
Kensington and Chelsea	158,902	23.3%	38,490	3.7%	9.8%	16,381	5.3%	6.0%	10,177	22.7%
Kingston upon Thames	147,218	3.6%	5,462	6.8%	1.2%	1,832	13.2%	0.6%	940	11.7%
Lambeth	266,143	9.8%	27,115	6.7%	2.7%	7,616	11.9%	1.3%	3,607	17.9%
Lewisham	248,910	5.0%	12,936	9.3%	0.9%	2,299	14.6%	0.3%	806	42.6%
Merton	187,924	2.9%	5,707	10.6%	0.7%	1,306	13.9%	0.3%	566	59.9%
Newham	243,820	3.8%	9,569	11.4%	1.1%	2,785	7.8%	0.5%	1,228	32.2%
Redbridge	238,666	3.7%	9,074	4.1%	1.5%	3,821	8.3%	1.0%	2,669	24.6%
Richmond upon Thames	172,345	3.5%	6,206	7.1%	1.1%	1,915	10.2%	0.6%	1,088	22.9%
Southwark	244,877	12.6%	32,111	6.0%	3.9%	9,989	7.9%	2.5%	6,590	19.4%
Sutton	179,799	1.4%	2,538	12.7%	0.1%	241	6.7%	0.0%	57	61.5%
Tower Hamlets	196,141	12.1%	24,689	5.1%	5.2%	10,835	9.1%	3.5%	7,280	11.8%
Waltham Forest	218,278	4.4%	9,963	6.0%	1.7%	3,873	3.9%	1.2%	2,914	11.5%
Wandsworth	260,393	6.3%	17,107	5.9%	1.6%	4,276	11.7%	0.8%	2,290	33.1%
Westminster	181,276	38.7%	72,939	5.7%	13.4%	25,722	4.8%	8.7%	16,772	11.8%

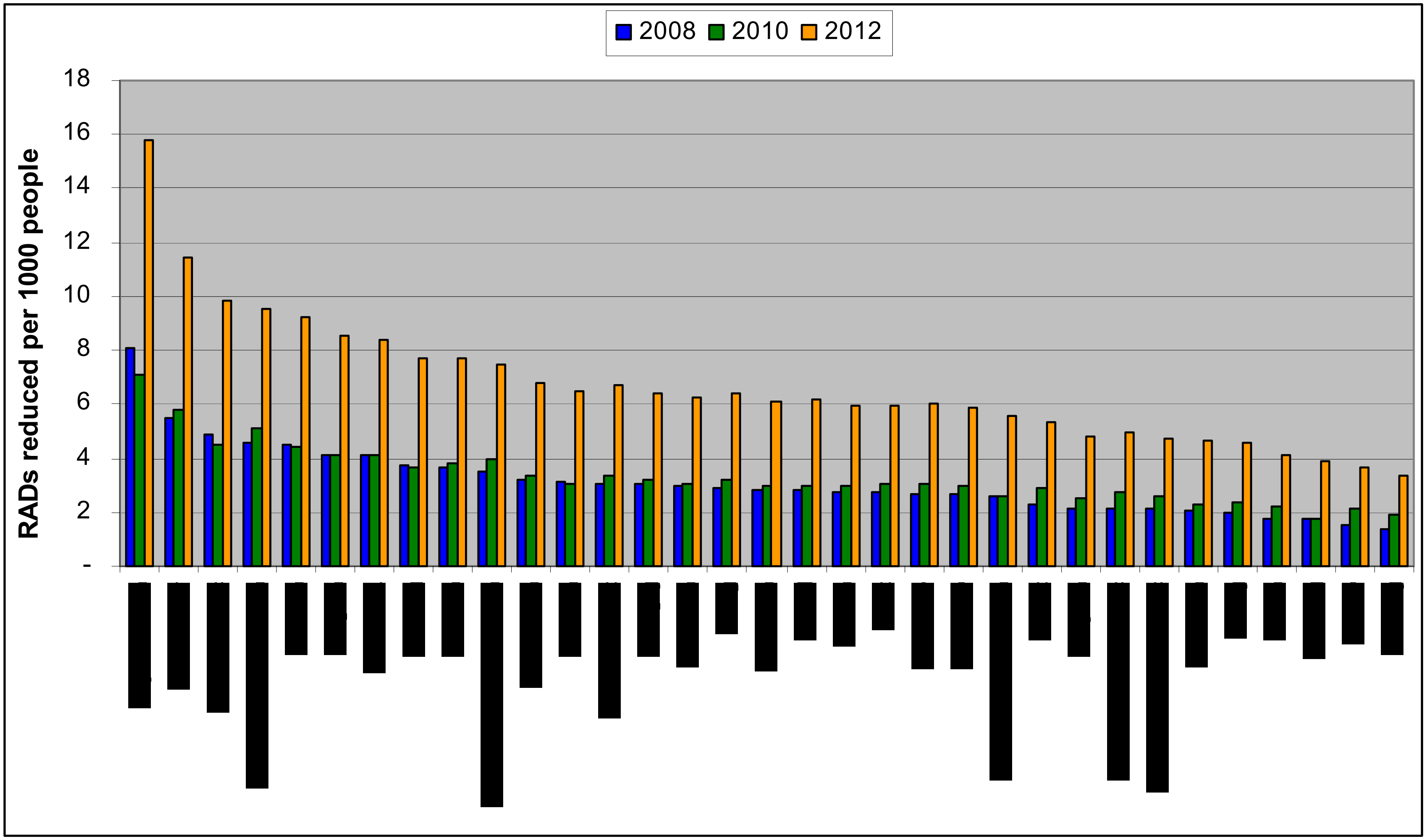
Source: Estimates based on concentration data provided by ERG, LEZ Phase 5 modelling (2006)

Proportion of Borough population in PM_{10} exceedence areas (pre-LEZ) (as measured by more than 10 exceedence days on an annual basis), and reduction in exceedence populations post LEZ implementation

Borough	Total population	2008			2010			2012		
		% popn exc. 10 days	Popn exc. 10 days	% reduction in exc. popn	% popn exc. 10 days	Popn exc. 10 days	% reduction in exc. popn	% popn exc. 10 days	Popn exc. 10 days	% reduction in exc. popn
Barking and Dagenham	163,932	0.9%	1,576	4.9%	0.2%	428	2.6%	0.1%	238	30.1%
Barnet	314,506	2.8%	9,174	5.0%	1.5%	4,832	8.0%	0.7%	2,380	19.4%
Bexley	218,316	0.9%	1,959	15.3%	0.1%	314	16.7%	0.0%	109	70.7%
Brent	263,507	2.4%	6,646	10.4%	0.7%	1,920	7.7%	0.5%	1,344	12.4%
Bromley	295,544	0.3%	790	11.6%	0.0%	108	59.9%	0.0%	12	98.4%
Camden	198,038	10.8%	22,337	3.3%	3.5%	7,417	6.0%	1.6%	3,352	15.6%
City of London	7,162	34.6%	2,581	10.5%	15.5%	1,171	14.7%	8.3%	633	54.0%
Croydon	330,562	1.6%	5,595	13.8%	0.2%	576	0.8%	0.1%	177	26.1%
Ealing	300,975	4.2%	13,207	7.5%	1.0%	3,255	13.1%	0.5%	1,661	5.6%
Enfield	273,530	3.1%	8,957	2.6%	1.6%	4,663	5.6%	1.0%	2,933	6.8%
Greenwich	214,412	3.1%	6,863	7.3%	1.2%	2,736	6.3%	0.7%	1,595	16.7%
Hackney	202,832	3.9%	8,151	12.1%	0.8%	1,771	1.0%	0.3%	752	17.6%
Hammersmith and Fulham	165,156	6.3%	10,824	7.1%	2.4%	4,249	6.1%	1.7%	3,013	11.6%
Haringey	216,498	2.2%	4,984	9.8%	0.3%	617	16.6%	0.1%	153	41.5%
Harrow	206,822	0.3%	540	13.2%	0.0%	51	25.7%	0.0%	32	60.5%
Havering	224,243	0.5%	1,059	4.3%	0.1%	302	5.8%	0.1%	146	59.4%
Hillingdon	243,065	1.4%	3,573	6.3%	0.4%	923	7.6%	0.2%	396	11.5%
Hounslow	212,340	3.6%	7,997	7.7%	1.4%	3,045	4.7%	0.9%	2,042	12.1%
Islington	175,792	6.1%	11,242	5.2%	1.8%	3,353	12.1%	0.5%	899	54.4%
Kensington and Chelsea	158,902	15.7%	26,010	2.6%	6.9%	11,551	9.5%	2.8%	4,695	15.0%
Kingston upon Thames	147,218	2.4%	3,665	6.2%	0.7%	1,052	5.1%	0.4%	667	12.6%
Lambeth	266,143	5.7%	15,746	7.6%	1.4%	3,970	9.4%	0.6%	1,788	28.6%
Lewisham	248,910	2.9%	7,500	11.6%	0.4%	1,160	10.6%	0.1%	292	35.0%
Merton	187,924	1.7%	3,272	4.0%	0.4%	722	7.0%	0.1%	118	17.8%
Newham	243,820	2.0%	5,086	3.7%	0.6%	1,587	17.8%	0.2%	452	10.0%
Redbridge	238,666	2.1%	5,330	5.0%	1.0%	2,435	11.3%	0.6%	1,453	13.4%
Richmond upon Thames	172,345	2.4%	4,352	5.4%	0.7%	1,307	11.3%	0.2%	309	46.9%
Southwark	244,877	6.9%	17,508	4.2%	2.6%	6,820	8.2%	1.1%	2,992	23.2%
Sutton	179,799	0.6%	1,146	13.2%	0.0%	44	0.0%	0.0%	22	0.0%
Tower Hamlets	196,141	8.8%	17,859	5.7%	3.6%	7,537	3.9%	2.3%	4,818	16.0%
Waltham Forest	218,278	2.7%	6,048	9.1%	1.3%	3,114	4.1%	1.0%	2,284	2.4%
Wandsworth	260,393	3.8%	10,264	8.3%	0.9%	2,572	8.9%	0.3%	728	39.6%
Westminster	181,276	20.9%	39,394	6.4%	8.5%	16,251	5.5%	4.9%	9,436	10.9%

Source: Estimates based on concentration data provided by ERG, LEZ Phase 5 modelling (2006)

Reduction in number of RADs in each year of LEZ scheme implementation (normalised by Borough population)



Reduction in number of RADs in each year of LEZ scheme implementation