ED48300

Technical and Non-technical Options to Reduce Emissions of Air Pollutants from Road Transport

Final Report to Defra

March 2005

ED48300

Title	Technical and Non-technical Options to Reduce Emissions of Air Pollutants from Road Transport
Customer	The Department for Environment, Food and Rural Affairs, the National Assembly for Wales, the Department of the Environment in Northern Ireland, and the Scottish Executive Environment and Rural Affairs Department.
Customer reference	CPEA13
Confidentiality, copyright and reproduction	Copyright AEA Technology Environment
File reference	AEAT/ED48300
Report number	AEAT/ED48300/R02
Report status	Final: Version D

Sujith Kollamthodi
AEA Technology Environment
154/1.04 Harwell
Didcot
Oxfordshire
OX11 0QJ
Telephone +44(0)870 190 6513
Facsimile +44(0)870 190 6327

	Name	Signature	Date
Author	Sujith Kollamthodi		31st March 2005
Reviewed by	Paul Watkiss		31st March 2005
Approved by	Paul Watkiss		31st March 2005

Contents

1 Introduction

The European Commission's Air Quality Framework Directive[1] and the associated First Daughter Directive[2] include challenging targets for the maximum allowable concentrations of nitrogen dioxide and particulate matter. Road transport is one of the largest contributors to emissions of these two pollutants, and reductions in emissions from this sector will be very important if future targets are to be achieved. Emissions and air quality modelling work carried out to date by Defra's Air Quality Expert Group and AEA Technology[3] indicates that the UK will not meet the limit values for NO_2[(a)] and PM_{10}[(b)] concentrations specified in the First Daughter Directive, or its own Air Quality Strategy targets in all areas of the UK. There is therefore a need to examine additional measures that could be used to reduce emissions from the road transport sector. After 2010 there is likely to be further pressure to improve air quality to an even greater extent and more measures may need to be implemented, with the ultimate long-term aim of achieving ultra-low or zero-emissions from the road transport sector.

AEA Technology Environment was commissioned by the Department for the Environment, Food and Rural Affairs (Defra), the Devolved Administrations, and the Department for Transport (DfT) to carry out an investigation of additional measures that could be used for reducing emissions from road transport over three different time scales: 2005 to 2010, 2011 to 2025, and 2025 to 2050. The first stage of this study consisted of undertaking a review of possible technical and non-technical options for reducing emissions[4]. Technical options include alternative fuels, new vehicle technologies, and emissions abatement equipment, whereas non-technical options include fiscal measures, traffic demand management, etc. The aim of the review was to identify potential emission reduction options, and to provide initial data on the unit costs, emissions abatement performance, and wider impacts of the options. The results of this review are presented in a separate report (AEAT/ED48300/E01).

The overall aims of the study have been to develop and assess possible deployment/ implementation scenarios for different technical and non-technical options, carry out an initial assessment of the specific costs and emissions benefits associated with each scenario, and to rank and prioritise the scenario options for further detailed investigation and emissions modelling. Additionally, the study has attempted to identify and assess combinations of options that could work together in packages to reduce emissions from road transport. The outputs from this study have also been collated into a searchable database of measures that provides details of the costs, emissions benefits and wider impacts of each option.

In order to rank and prioritise options for further investigation, the study has made use of decision analysis techniques; in particular, much of this work has been carried out using Multi-Criteria Decision Analysis (MCA). This technique is particularly useful where there is limited quantitative data available, as is the case for options relating to the 2011-2025 and 2025-2050 time periods. Furthermore, MCA is useful where there are large numbers of criteria that are being assessed. As the study has tried to take into account the wider environmental, traffic-related, and social impacts of each option, it was necessary to make use of a technique such as MCA to facilitate the decision process.

Compared to the two later time periods, the scenarios constructed for the 2005-2010 time period have been developed in much more detail, with quantified estimates of the total costs and emissions benefits associated with each option. This additional level of detail has meant that it has been possible to use both Multi-Criteria Analysis and the more traditional Cost-Benefit Analysis approach to assess scenario options for this time period.

This final report should be read in conjunction with the initial review of technical and non-technical measures that was carried out at the beginning of the study (report reference

---

[a] nitrogen dioxide

[b] particulate matter with an aerodynamic diameter not greater than 10 μm

AEAT/ED48300/R01). The initial review report provides more detailed information on many of the options (particularly options for implementation between 2005 and 2010) that is not replicated in this report.

The following gives an overview of the structure of this report:

Section 2 provides detailed information on the various methodologies that have been used throughout this study to construct, assess, rank, and prioritise the different scenario options.

Section 3 provides information on the scenarios that have been developed for each of the technical and non-technical options that could be implemented between 2005 and 2010. Detailed quantitative assessments of the costs and emissions abatement performance associated with each scenario have been provided, along with qualitative assessments of the wider impacts of each scenario.

Section 4 provides details of option scenarios for the 2011-2025 time period. Where possible, quantified information on the costs and emissions benefits of each scenario has been provided, although it has often not been possible to provide this level of detail. For each scenario, a qualitative assessment of the costs, emissions abatement performance, and wider impacts is presented.

Section 5 provides details of scenarios for the 2025-2050 time period. For options in this time period, no quantitative data was available, and the assessments have been purely qualitative in nature.

Section 6 presents the results of the Multi-Criteria Decision Analysis procedures used to rank and prioritise options in each of the three time periods covered by this study. This section of the report describes and reports the results of each MCA run, and provides lists of prioritised options for each time period.

Section 7 presents the results of the Cost-Benefit Analysis of scenario options for the 2005-2010 time period. This analysis is based on comparing the total costs with the total monetary value of emissions benefits for each option. The final output of this analysis is a rank ordering of options based on net emissions reduction benefits.

Section 8 of the report provides an initial analysis and investigation of possible packages or combinations of individual scenario options. For the 2005-2010 time period, estimates of the costs and emissions benefits of different option combinations are provided and discussed. For the other time periods, a qualitative approach has been taken to selecting suitable option combinations.

Section 9 of the report provides a summary of the study conclusions and recommendations.

2 Study Methodology

2.1 Overview and assumptions

The main objective of the study was to identify and prioritise options that could contribute to reducing NOx and PM_{10} emissions from road transport in three distinct time periods: 2005-2010, 2011-2025, and 2025-2050. Whereas the initial review (AEAT/ED48300/R01) provided an overview of the options that could possibly be used for reducing road transport NOx and PM_{10} emissions, and gave an indication of the likely unit costs and emissions abatement performance of different options, the work described in this report provides a more detailed analysis of the options, and in particular, scenarios have been developed for each option, and estimates of the total UK costs and emissions benefits associated with scenarios that could be implemented between 2005 and 2010 have been made. With regard to scenario options that could be implemented in later time periods, a more qualitative approach has been taken to assessing the cost and emissions benefits, due to a lack of robust data. A qualitative assessment of the wider impacts associated with each option has also been carried out.

The methodology that has been used for this work incorporates a number of different elements. These are as follows:

Scenario development
This consisted of identifying hypothetical scenarios for the manner in which individual options could be deployed or developed in future years (see **Section 2.2** for more details).

Assessment of capital and operating costs associated with scenarios
Most scenario options will incur additional costs over the baseline “business as usual” scenario. The assessment of capital and operating costs has scaled up the unit costs associated with an option to take account of specific factors in each deployment scenario. For example, where a scenario assumes that a technology will be adopted by a certain percentage of the vehicle fleet, the number of vehicles affected has been estimated, and the unit costs have been scaled up in the appropriate manner. Where there are cost reductions (e.g. reductions in fuel use), these have also been estimated (see **Section 2.3** for more details).

Assessment of the emissions abatement performance of options
For the 2005-2010 time period, quantified assessments of the reduction in total UK road transport NOx and PM_{10} emissions associated with each scenario have been made. Where possible, changes in CO_2 emissions have also been estimated. For the later time periods, qualitative assessments have been carried out (see **Section 2.4** for more details).

Assessment of the wider impacts of options
A range of wider impacts relating to other pollutant and CO_2 emissions, traffic impacts, social impacts and feasibility have been assessed in a qualitative manner (see **Section 2.5** for more details).

Multi-criteria analysis of options
The outputs from the costs, emissions, and wider impacts assessment have been combined to enable Multi-Criteria Analysis to be used to rank and prioritise the options in each time period for further investigation. (See **Section 2.6** for more details)

Cost-benefit analysis of options
To complement the MCA process, cost-benefit analysis (CBA) has also been carried out for options that could be implemented during the 2005-2010 time period. The benefits assessment has been solely based on the monetary value of NOx, PM_{10}, and CO_2 emissions benefits. (See **Section 2.7** for more details)

Identification of options for further investigation
The results of the Multi-Criteria Analysis and the Cost benefit analysis have been used to develop lists of prioritised options that should be investigated in further detail for each time period.

Identification of combinations of options for further investigation
The results of the study have been used to identify combinations of options that could work together to provide greater emissions benefits than implementing single options (see **Section 2.8** for more details).

The following sections provide more details of the specific methodologies that have been used in this study to carry out each of the steps outlined above.

2.2 Scenario development

The initial review of technical and non-technical options concentrated on providing descriptive information on the available options, as well as providing a summary of the potential costs and unit emissions abatement performance that could be achieved, based on previous implementations, published data, and information obtained from industry stakeholders. In particular, the data on technical options (e.g. retrofit abatement equipment and alternative technologies) focused on providing information on the emissions abatement performance of individual vehicles, and did not place the options in the context of what effect the widespread uptake or deployment of an option would have on total UK emissions of NOx and PM_{10}, and what the costs associated with deploying options on a national or local scale would be. This part of the study attempts to develop hypothetical scenarios that represent possible options for the deployment of different technical and non-technical measures. It should be noted that all the scenarios developed for this part of the study are based on assumptions as to what might be possible over a particular time scale. Examples of the types of scenarios that have been developed include:

- 10% of heavy duty vehicles to be equipped with SCR technology by 2010
- 2% of the UK bus fleet to run on Compressed Natural Gas by 2010
- Low Emission Zones to have been implemented in London and the eight largest metropolitan areas by 2007

The level of uptake of technical and non-technical options is uncertain, particularly over long time frames such as the 45-year time period covered by this study. With this in mind, the scenarios have been developed to establish the possibilities for different options, and do not provide forecasts of what *will* happen in future years. In most cases, scenarios were developed to reflect the feasible uptake of different options at certain points in time. For some options, low and high uptake scenarios have been proposed to reflect uncertainty in the future level of uptake. However, it has not been possible within this study to propose low and high uptake scenarios for all options. In developing the scenarios, account was also taken of the current level of uptake for particular technologies or measures in order to help develop appropriate levels of uptake for each scenario.

The scenarios developed have then been assessed to estimate the total cost of adopting the measure and the reduction in total UK road transport emissions that would result from the adoption of the measure. The methodologies used to assess these aspects are discussed in more detail in Section 2.3 and Section 2.4.

For technical options, the development of possible future scenarios has taken into account a number of factors including the effect that the option has on emission factors for individual vehicles, the total number of vehicles that would be affected in the hypothetical scenario, and projections for baseline road transport emissions between 2005 and 2010. Baseline road transport emissions projections (NOx and PM_{10}) for all years between 2005 and 2025 have been modelled for all vehicle types, using data from the National Atmospheric Emissions Inventory (NAEI)[5] including speed dependent emission factor data, estimates for the split between urban, rural, and motorway drive cycles, and estimates for average speed in each drive cycle for each vehicle type. The NAEI was also used to provide estimated baseline projections for:

- the number of vehicles on the road in each year between 2005 and 2025
- the number of new vehicle sales in each year between 2005 and 2025

As detailed emissions modelling has not been carried out for all options, and in many cases simple assumptions have been made with regard to the rates of uptake of different options, it should be noted that the initial scenarios developed for this work will need to be revised for any subsequent, more detailed research carried out following completion of this study.

2.3 Cost assessment

2.3.1 Overview

The study focused on three different time periods, and different methods have had to be used to assess the possible costs associated with measures in each of the time periods. For the period covering 2005 to 2010, it has been possible to carry out detailed studies to understand what the likely capital and operating costs associated with each measure would be. Options suitable for this time period are either available now, or will soon be available, and hence relatively accurate information on costs has been obtained. Much of this information was gathered from industry stakeholders and governmental policy experts during the first phase of this study and can be found in the review report[4]. This is particularly the case for technical options such as retrofit emissions abatement equipment, alternative fuels, and hybrid technologies, where much data is already available. For non-technical options, whilst data on the costs of implementing different options exists, care must be taken in how this data is handled. In particular, it must be recognised that the costs associated with implementing a non-technical option in one location, are unlikely to be replicated if the same type of option is introduced elsewhere. This is primarily due to the fact that the manner in which many non-technical options such as Low Emission Zones, access control measures, and public transport priority schemes are deployed will depend to a large degree on the basic infrastructure design (road design and layout, etc) that is already in place. In some cases, it has been necessary to make simplified assumptions about the costs of implementing non-technical options, as there was not enough data available to make more robust estimates. For example, it has been assumed that the costs of setting up and operating Low Emission Zones in the largest urban areas outside of London are the same in each urban area. In reality, the costs would differ in each area due to local differences in infrastructure, geography, and traffic etc, but in order to assess these costs on a local basis, a much more in-depth study would be required.

All costs reported in this study are relative to the baseline, business-as-usual situation. The baseline situation assumes that no additional measures are implemented over and above those already included in the ten-year transport plan. Additional costs, therefore, only relate to those measures that would not otherwise have been introduced. For example, the additional costs associated with an option to increase the uptake of low emission passenger cars are the additional capital costs of such vehicles *over and above* the capital cost of conventional vehicles. Furthermore, in this example, there may be reductions in annual operating costs due to low emission passenger cars being more fuel-efficient than conventional vehicles. In this case, the annual reduction in operating costs against the baseline situation (i.e. no increased uptake of low emission vehicles) is reported.

For the later time periods (2010-2025 and 2025-2050), it becomes less straightforward to assess the costs associated with different measures, as detailed information is not always available. Where data is available, an initial assessment of the costs has been made, but in the main, a qualitative assessment of the scale of the capital and operating costs has been made instead.

This is particularly the case for the 2025-2050 time period, where no accurate data on the likely costs of implementing options is currently available.

Because different measures have different technical and economic lifetimes, it has been necessary to present all cost data in terms of total annual costs. The total annual costs consist of the annualised capital costs and the net annual operating costs. The following sections discuss in more detail how capital costs and operating costs have been dealt with, and what assumptions have been made. It should be noted that where cost data is available it has been presented in 2004 prices.

2.3.2 Capital costs

Where detailed data is available, all capital costs have been presented in terms of annualised capital costs and the net present value of capital costs over a particular time period (e.g. 2005-2010). This allows different options, which may have different technical or economic life times to be compared on an equivalent basis. Annualised capital costs for all options with a lifetime of less than 30 years have been calculated using a discount rate of 3.5%, as recommended by HM Treasury[c]. Assumptions for the technical lifetimes applied to measures are based on information from literature reviews, or from data obtained from industry and Government stakeholders. Where no published data is available, appropriate assumptions for the technical lifetime of a measure have been made. For measures that relate to the purchase of new vehicles, it has been assumed (based on information obtained from the Department for Transport), that the average technical life time of a passenger car is 12 years, and for light vans the life time is 11 years. For heavy goods vehicles and buses, the average lifetime has been assumed to be 10 years.

2.3.3 Operating costs

2.3.3.1 Fuel costs

Depending on the particular type of measure, various annual operating costs have been taken into account. For many technical measures, the operating costs relate to changes in the amount of fuel used by vehicles. Changes in fuel costs have been calculated on the basis of assuming a constant retail price for road diesel and petrol of 85 pence per litre, inclusive of fuel duty and VAT. This figure has been used for estimating additional or reduced fuel costs associated with all petrol or diesel-engined light duty vehicles, and for all heavy goods vehicles. This retail price is based on the average UK fuel prices as reported in the AA Fuel Price Report October 2004. In this report, the UK average fuel price for unleaded petrol is given as 83.9 pence per litre and the average price for diesel is 86.1 pence per litre. To simplify calculations, the average of the petrol and diesel prices has been used.

In addition to petrol and diesel, the costs for a range of other fuels have also been assessed, including Compressed Natural Gas (CNG), Water Diesel Emulsion (WDE) fuel, and biofuels. Information from the Natural Gas Vehicle Association has been used to assess the fuel costs associated with options relating to increased uptake of CNG powered vehicles; a retail price of 51 pence per kg has been used for CNG fuel. For Water Diesel Emulsion fuel, information from one of the suppliers of this type of fuel has indicated that this fuel typically retails at a price 3 pence per litre higher than conventional diesel; for the purposes of this study, a retail price of 88 pence per litre has therefore been assumed. The following table sets out the retail prices of each of these fuels, as used in this study, along with details of the amount of duty and VAT included in the retail price. Fuel duty is currently levied at a rate of 47.1 pence per litre for ultra low sulphur petrol and diesel fuels. For road fuel gases such as CNG, the rate of duty is 9.0 pence per kilogram (equivalent to around 7.0 pence per litre). For the purposes of this study, it has been assumed that fuel duty levels will not change between 2005 and 2010.

[c] HM Treasury Green Book, Appraisal and Evaluation in Central Government.

Table 2.1: Comparison of fuel prices and duty rates

Fuel type	Retail price per litre (£/litre)	Fuel duty (£/litre)	VAT (£/litre)	Commodity price (£/litre)
Petrol	£0.85	£0.47	£0.13	£0.25
Diesel	£0.85	£0.47	£0.13	£0.25
Compressed Natural Gas	£0.39	£0.07	£0.06	£0.26
Water Diesel Emulsion fuel	£0.88	£0.47	£0.13	£0.28

Due to the Bus Service Operators Grant (BSOG), a slightly different approach has been taken for calculating changes in fuel costs for options relating to buses. The BSOG allows bus operators to claim a rebate on the duty paid on the diesel fuel that they use. For diesel, the rebate is 80% of the duty, whilst for road fuel gases such as CNG, operators are eligible for a rebate of 100% of the duty. In practice, this means that operators can claim 36.7 pence for every litre of diesel or WDE fuel used, or 9.0 pence for every kilogram of CNG used. For the purposes of this study, it has been assumed that the BSOG will continue to operate in this manner between 2005 and 2010. Table 2.2 below presents the costs of diesel, WDE fuels, and CNG to bus operators after the impact of the BSOG has been taken into account.

Table 2.2: Comparison of retail fuel prices with cost of fuel to bus operators after the Bus Service Operators Grant has been taken into account (prices include VAT)

Fuel type	Retail price per litre (£/litre)	Price to bus operators (£/litre)
Diesel	£0.85	£0.41
Compressed Natural Gas	£0.39	£0.31
Water Diesel Emulsion fuel	£0.00	£0.44

2.3.3.2 Other operating costs and revenues

Where data is available on other operating costs associated with a measure, these have been included. Other operating costs might include additional maintenance costs, or the costs of additives such as urea for Selective Catalytic Reduction systems. For non-technical options such as Low Emissions Zones, there are often annual operating costs associated with enforcing the measure. If there are estimates for annual revenues related to a measure, then these have also been included in the cost assessment.

2.4 Assessment of emissions abatement performance

Where possible, the emissions abatement performance of the different options has been assessed against the baseline scenario. The baseline scenario assumes that no options other than those included in the ten year transport plan will be implemented between now and 2010. Data on traffic growth has been obtained from the Department for Transport's National Transport Model, and this has been fed into a road transport emissions model. Projections for baseline emissions are available for NOx and PM_{10}.

For all options that could be implemented between 2005 and 2010, estimates of the reduction in total emissions of NOx and PM_{10} against the baseline scenario have been made for each year. For technical options where the option leads to a change in the emission factors for a particular type or types of vehicle, these changes have been fed into the NAEI speed dependent emission factor model to estimate the effect on total emissions. It must be stressed that a number of different methods have been used to estimate the emissions abatement performance of different options. The most robust emissions analysis is based on the results of detailed modelling carried out by Netcen during 2004 on specific options and deployment scenarios. Options where detailed analysis has been carried out are as follows:

- Euro 5 (light duty) emissions standards
- Scrappage scheme for pre-Euro and Euro 1 vehicles
- Increased uptake of low emission passenger cars / hybrid passenger cars
- Water Diesel Emulsion fuel for buses and HGVs
- Lorry Road User Charging Scheme
- National Road Pricing scheme (post 2010)

Data on the percentage emissions abatement performance of technical options were obtained from industry and government stakeholders; a more detailed discussion of the unit abatement performance of the various technical options can be round in the review report[4].

For other options considered in the 2005-2010 time period, estimates of emissions abatement performance have been based on simplified emissions modelling and analysis work, as well as work carried out for previous studies, including the London Low Emission Zone Feasibility Study[6] and the Evaluation of the Air Quality Strategy[7].

It has also been recognised that there is a need to consider the impacts that some options may have on primary NO_2 emissions[d]. It is known that some exhaust after-treatment and particulate control technologies lead to an increase in the proportion of NOx emitted as NO_2. In particular, it should be noted that Continuously Regenerating Trap (CRT) diesel particulate filters can increase the proportion of NOx emitted as NO_2. In order to regenerate the particulate trap (i.e. burn off the particulate matter collected), CRT filters convert a proportion of the nitric oxide emissions in the exhaust stream to NO_2, which is then used for trap regeneration. For CRT-equipped diesel vehicles, the proportion of NOx emitted directly as NO_2 can be as high as 50% (compared to approximately 25% for diesel vehicles not equipped with this technology)[3]. This has important implications for the manner in which future NO_2 pollutant concentrations are predicted. The air quality modelling methods that Netcen carries out in support of policy development make use of empirically-based assessments of the ratio between NO_2 and NOx concentrations at roadside locations (based on automatic monitoring station measurements of the NO_2:NOx concentration ratio). This methodology implicitly takes account of current primary NO_2 emissions, but has the disadvantage that any increases in the proportions of direct NO_2 emissions in future years due to the uptake of new technologies are not taken into account in air quality modelling for future years. Sensitivity analysis has indicated that increased primary NO_2 emissions would lead to an increase in roadside NO_2 concentrations[3]. With all of this in mind, the potential impact of individual specific options on primary NO_2 emissions has been discussed where appropriate.

2.5 Assessment of the wider impacts of options

2.5.1 Overview

In addition to the costs and emissions benefits associated with the different options, there are other impacts that should be taken into account when assessing transport schemes. These

[d] Primary NO_2 emissions are those that are directly emitted by vehicles. Primary NO_2 emissions can result from both engine combustion processes and from some exhaust after-treatment technologies that promote conversion of nitric oxide (NO) to NO_2. Secondary NO_2 is generated in the atmosphere through the reaction between vehicle emissions of nitric oxide and ground level ozone, or via reactions between alkyl per-oxy radicals and nitric oxide.

impacts cannot always be quantified in a simple fashion, and for this reason it has been necessary in most cases to provide a qualitative assessment of the likely impacts of each option against the various performance criteria.

Qualitative scores have been used to describe how each option performs against a range of performance criteria, with scores ranging from +3 to indicate a very strong positive impact, to –3 for a very strong negative impact. Table 2.3 below provides details of what each score relates to.

Table 2.3: Definitions associated with qualitative scores

Description of effect	Qualitative score
Very strong positive effect	3
Strong positive effect	2
Weak positive effect	1
No effect	0
Weak Negative effect	-1
Strong negative effect	-2
Very strong negative effect	-3

If, for example, a scenario is given a rating of "+3" against NOx emissions, this means that there is a very large reduction in NOx emissions due to the implementation of the scenario. Likewise, positive scores against cost criteria indicate that there is a reduction in costs associated with implementing the scenario. The qualitative scores applied to each option were agreed in conjunction with both industry stakeholders and government policy experts.

The wider impact performance criteria have been grouped into a number of different category themes, as follows:

- Other emissions and pollutants
- Traffic impacts
- Social impacts
- Acceptability and feasibility

The following sections describe the individual performance criteria that have been included in each of these category themes.

2.5.2 Other emissions and pollutants

Whilst the primary focus of this study has been on measures that reduce emissions of NOx and PM_{10}, and to a lesser extent on the greenhouse gas CO_2, other pollutants and emissions have also been considered, but in a less comprehensive manner. Where available, qualitative information on the effect that each scenario option would have on emissions of the following pollutants has been included:

- Carbon monoxide (CO)
- Hydrocarbons (HC)

Additionally, the impact of options on the generation of ground level ozone has also been considered.

2.5.3 Traffic impacts

In addition to impacts on pollutant emissions, many of the options will have an effect on traffic parameters. The parameters that have been included as wider impact performance criteria for this study are as follows:

- Environmental noise
- Accident rate
- Traffic congestion

2.5.4 Social impacts

An assessment of the likely social impacts of different options has also been carried out. The social impacts that have been included are as follows:

- social cohesion (defined in the European Union's Social Policy Agenda[8] as an objective "to prevent and eradicate poverty and social exclusion, and promote the integration and participation of all in economic and social life");
- quality of life; and
- distributional effects (i.e. does an option unfairly penalise a particular sector of society).

Quantitative data on the performance of options against these criteria were not available, and hence a purely qualitative assessment of social impacts has been carried out.

2.5.5 Feasibility of options

In addition to the impacts that options would have on all of the performance criteria described above, the feasibility of implementing each option has also been taken into account. This has been achieved by providing information on how acceptable options would be to the public or industry, and by providing information on how practical it would be to implement each option. For options in future time periods, practicality has been assessed with regard to the likely situation in future years; for example the practicality of widespread uptake of hydrogen powered vehicles in the time period 2025-2050 has been assessed in the context that this technology will be more readily available by that time period. As with social impacts, a purely qualitative assessment has been carried out with regard to the feasibility of implementing options.

2.6 The use of Multi-Criteria Analysis to prioritise options for further investigation

Traditionally, transport schemes and options might be assessed using Cost-Benefit Analysis techniques, where impacts (such as emissions reductions or the number of lives saved due to the implementation of the option) can be quantified in terms of their monetary values. As part of this study, a cost-benefit analysis (taking only the monetary value of emissions benefits into account) has been carried out to assess the options that could be implemented during the 2005-2010 time period, and the methodology used for this assessment is discussed in more detail in Section 2.7. However, the limitation with this approach is that other wider impacts are not taken into account in the analysis, and whilst it is possible to provide monetary values for some other impacts, such as changes in accident rates and congestion, in order to do this, detailed information on the effects that options have on each of these parameters would be required. Such information is not available for most options at this point in time; detailed and extensive transport modelling work that is outside of the scope of this study would be required in order to obtain such information. Furthermore, some parameters such as social cohesion, practicality, and public/industry acceptability, would be very difficult to quantify in monetary terms.

One method of including the wider impacts in the assessment and prioritisation of options is to use Multi Criteria Analysis (MCA). The technique is particularly suited to options where there are relatively large numbers of performance criteria against which the options are being judged, and where there is a lack of detailed, quantitative data. A key feature of MCA techniques is the use of performance matrices where each row describes an option, and each column describes the performance of the option against a particular criterion. In this study, the MCA performance matrices used include combinations of quantitative estimates for the costs and emissions abatement performance of options, and qualitative data on the performance of individual options against criteria such as the effect on accident rate, social inclusion, and traffic congestion. An example of a performance matrix is given below in Figure 2.1.

Wider impacts of options – 2005 to 2010							
Options	Annualised capital cost (£millions)	Annual operating cost (£millions)	estimate of NOx emissions abatement (Tonnes)	estimate of PM_{10} emissions abatement (Tonnes)	CO emissions	HC emissions	Ground level ozone
SCR with diesel particulate filter (10% uptake on heavy-duty	£22.10	£38.51	13,495.7	106.2	2	1	3
EGR with diesel particulate filter (heavy-duty vehicles)	£25.26	£43.31	9,639.8	283.3	2	2	2
Water Diesel Emulsion fuels for heavy duty vehicles	£0.00	£5,857.42	6,358.9	202.8	0	0	2
Scrappage scheme for pre-Euro and Euro I cars	£0.00	£30.36	7,643.4	299.6	1	0	1
Low Emission Zones (Low cost estimate)	£30.39	£15.00	1,870.8	389.1	3	1	1
Car clubs / car sharing schemes	£1.25	£5.24	40.6	6.8	1	1	0
MAX	£30.39	£5,857.42	13,495.7	389.10	3.00	2.00	3.00
MIN	£0.00	£5.24	40.6	6.80	0.00	0.00	0.00
RANGE	£30.39	£5,852.19	13,455.1	382.30	3.00	2.00	3.00

Figure 2.1: Example of a performance matrix as used in Multi Criteria Analysis

The assessment of scenario options, as described in Sections 2.3, 2.4, and 2.5, produced a series of cost data, emissions data, and numerical scores for each option against a range of different performance criteria. The results of these assessments were used as the input data for the Multi-Criteria Analysis. Due to their being much more data available for the nearest time period, options covering 2005-2010 have the most comprehensive scoring. For the later time periods, robust quantitative data was not always available, and it was necessary to rely to an increasing degree on qualitative scores to assess the likely impacts of different options.

The next step in the MCA process was to normalise the numerical scores against each criteria in the performance matrix to a common scale. Typically, all the scores are normalised so that they appear on a scale between 0 and 100 (“0” indicates the least preferred option and “100” the most preferred option). The results of the normalisation process are shown below.

Wider impacts of options – 2005 to 2010							
Options	Annualised capital cost (£millions)	Annual operating cost (£millions)	NOx emissions	PM_{10} emissions	CO emissions	HC emissions	Ground level ozone
SCR with diesel particulate filter (10% uptake on heavy-duty vehicles)	27.3	99.4	100.0	26.0	66.7	50.0	100.0
EGR with diesel particulate filter (heavy-duty vehicles)	16.9	99.3	71.3	72.3	66.7	100.0	66.7
Water Diesel Emulsion fuels for heavy duty vehicles	100.0	0.0	47.0	51.3	0.0	0.0	66.7
Scrappage scheme for pre-Euro and Euro I cars	100.0	99.6	56.5	76.6	33.3	0.0	33.3
Low Emission Zones (Low cost estimate)	0.0	99.8	13.6	100.0	100.0	50.0	33.3
Car clubs / car sharing schemes	95.9	100.0	0.0	0.0	33.3	50.0	0.0

Figure 2.2: Normalisation of scores

In the full analysis carried out in this study, the performance criteria have been grouped into five category themes: costs, emissions, traffic impacts, social impacts, and feasibility. A weighting factor is applied to each theme to reflect the theme's relative importance, and the individual criteria within each theme are also weighted to indicate their relative importance within the theme.

Example weighting factors for themes and individual performance criteria are shown in Figure 2.3 below. In the example, the red-ringed figure (40) is the weighting factor that has been applied overall to the cost theme, and it can be seen that individual weighting factors of 60 and 40 have been applied to capital and operating costs within this theme. The weighting factors used in this study were developed during consultation with government policy experts. In practice, a number of different sets of weighting factors have been used, and the analysis was repeated a number of times to identify the impacts of the different weighting factors.

Wider impacts of options – 2005 to 2010													
Options	Annualised capital cost (£millions)	Annual operating cost (£millions)			NOx emissions abatement (Tonnes)	Particulate emissions	CO emissions	HC emissions	Ground level ozone			Total	Rank
Weighting	60	40	100		16	40	1	6	9	100			
				40							60		
SCR with diesel particulate filter (10% uptake on heavy-duty vehicles)	59.8	3.4	63.2	25.3	6.6	2.0	0.7	1.7	9.0	19.8	11.9	37.2	2
EGR with diesel particulate filter (heavy-duty vehicles)	59.7	3.4	63.1	25.2	4.6	5.4	0.7	3.3	6.0	20.1	12.0	37.3	1
Water Diesel Emulsion fuels for heavy duty vehicles	60.0	0.0	60.0	24.0	3.0	3.9	0.0	0.0	6.0	12.9	7.8	31.8	5
Scrappage scheme for pre-Euro and Euro I cars	60.0	3.4	63.4	25.4	3.7	5.8	0.3	0.0	3.0	12.7	7.6	33.0	4
Low Emission Zones (Low cost estimate)	59.7	3.4	63.1	25.2	0.9	7.5	1.0	1.7	3.0	14.0	8.4	33.6	3
Car clubs / car sharing schemes	60.0	3.4	63.4	25.4	0.0	0.1	0.3	1.7	0.0	2.1	1.3	26.7	6

Figure 2.3: Weighting factors for themes and performance criteria

Once the weighting factors have been applied, the scores for a particular option across all of the different performance criteria can be summed to obtain a total score for the option. In the above example, all of the figures in shaded boxes in a single row would be summed to arrive at the total score for the given option. The option that at the end of the analysis has the highest total score is the "most preferred" option (in the above example the most preferred option would be EGR for heavy duty vehicles). As mentioned earlier, the analysis is usually repeated a number of times using different weighting factors to identify a short list of options.

2.7 Cost-benefit analysis for prioritising options for further investigation

2.7.1 Monetary valuation of changes in NOx and PM_{10} emissions

For options that could be implemented between 2005 and 2010, cost-benefit analysis has been carried out in addition to Multi-Criteria Analysis. Estimates of the monetary value of the benefits of reductions in air pollution associated with each option have been made using a methodology that is consistent with that used in previous work undertaken to evaluate the National Air Quality Strategy[9]. As part of this previous work, unit pollution costs (costs per tonne of pollution) were derived and these values have been used in this study. For NO_X emissions, UK-wide central low and central high values per tonne of pollutant emitted from the transport sector were originally derived; in this study only the central high values have been used.

For PM_{10} emissions, a more detailed approach is needed. The location of primary PM_{10} emissions is very important, as the local population density exposed to pollution must be taken into account. Emissions in large, densely populated urban areas have impacts that are an order of magnitude higher, per unit tonne of emissions, than rural areas. As part of the study, we have analysed the population-weighted exposure from PM_{10} emissions in different locations in the UK. The relative economic damage costs, per tonne of emissions, are shown below, set against emissions in central London on the left hand side (the area with highest population density), through to rural emissions on the far right.

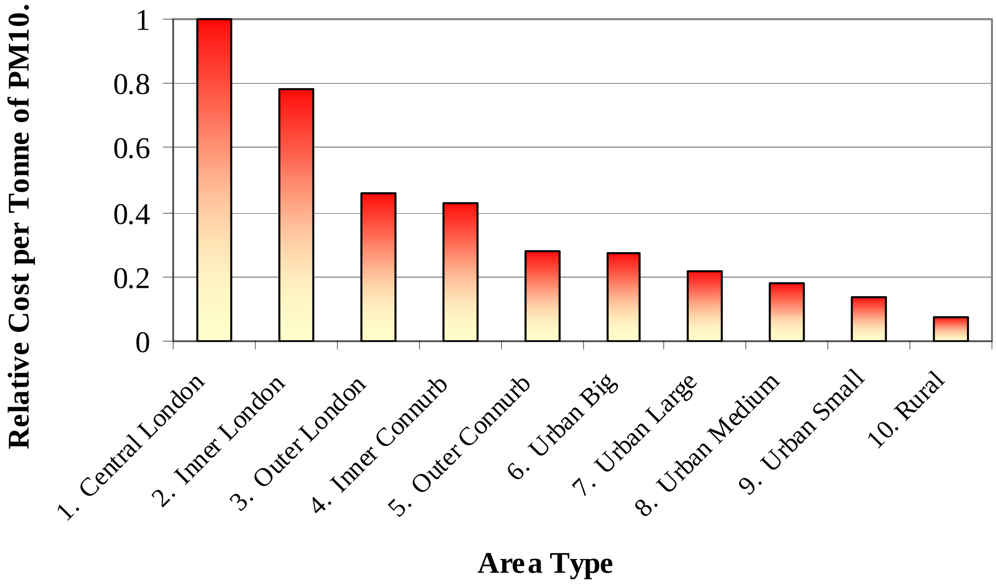

Figure 2.4: Relative unit pollution costs for a tonne of primary PM_{10} emitted in urban and rural areas in the UK (left: Central London; right: rural). Cost per tonne in central London = 1

The areas types presented above (area types 1-10) in Figure 2.4 are the 10 area types that are currently set up within the Department for Transport's National Transport Model. Details of the area types are given in Table 2.4 below. The assessment of PM_{10} emissions benefits has therefore taken into account the locations that would be affected by the implementation of particular measures. For example, Low Emission Zones have been assumed to only affect emissions in Area Types 1 to 5 (London and the conurbations), and the assessment of the monetary value of emissions benefits has taken this factor into account.

Table 2.4: DfT National Transport Model FORGE Area Type codes and descriptions

FORGE Area type code	Description	Population
1	Central London	
2	Inner London	
3	Outer London	
4	Inner Conurbation	
5	Outer Conurbation	
6	Urban Big	> 250,000
7	Urban Large	>100,000
8	Urban Medium	> 25,000
9	Urban Small	> 10,000
10	Rural	

A number of important caveats are associated with the benefit values used in the analysis (and reflected in all results). These are as follows:

- The monetary values do not include trans-boundary pollution impacts. They only include health and non-health impacts that occur in the UK. They are therefore a sub-total of all impacts, or benefits of emissions reductions.
- The health benefits above do not include benefits from reductions in ozone or disbenefits from increases in urban ozone due to reductions in urban NOx emissions.
- Additional benefits from reducing other pollutants (e.g. VOCs) are not included.

- The values for NO_X include secondary particulate (PM_{10}) formation (nitrates).
- The analysis assumes no threshold of effects and implements concentration-response functions linearly.
- Future life years lost have been discounted using 1.5% discount rate.
- All chronic mortality impacts use original $PM_{2.5}$ functions to PM_{10} pollution metric.
- The numbers exclude several categories of impacts, notably: impacts on ecosystems (acidification, eutrophication, etc), impacts on cultural or historic buildings from air pollution, mortality from PM_{10} on children, chronic morbidity health effects from PM_{10}, morbidity and mortality from chronic exposure to ozone, change in visibility (visual range), effects of ozone on materials.
- Environmental costs of air pollution vary according to a variety of environmental factors, including overall levels of pollution, geographic location of emission sources, height of emission source, local and regional population density, meteorology etc. These numbers take these issues into account to a certain degree only.

Cost benefit analysis has only been used to rank and prioritise options for the 2005-2010 time period as there is not enough quantitative data available on the costs and emissions benefits of options that could be implemented in the later time periods.

2.7.2 Monetary valuation of changes in CO_2 emissions (social costs of carbon)

In addition to assessing the economic benefits of reductions in air pollution that would arise due to the implementation of individual options, the study has also assessed the economic impacts of changes in CO_2 emissions. The economic impacts of CO_2 emissions are commonly grouped together as the social costs of carbon. These costs include factors such as agricultural and ecosystem impacts, as well as increased mortality due to climate change effects. A Government Economic Service Working Paper[10] recommends the use of a figure of £70 per tonne of carbon for the year 2000 as an estimate for the social cost of carbon, with a sensitivity range of between £35 and £140 per tonne of carbon. For CO_2 emissions, this equates to a figure of approximately £19 per tonne of CO_2, with lower and upper sensitivity bands of £9.55 and £38 per tonne of CO_2 respectively. Using this methodology, for each year after 2000, the value of £70 per tonne of carbon increases by £1 per tonne per year.

2.8 Assessment of combinations of options

2.8.1 Combinations of options for the 2005-2010 time period

The results of the MCA and CBA ranking and prioritisation activities have been used to identify options that could be combined into packages of options that could achieve greater benefits. A simple assessment for a number of option combinations has been carried out by summing the costs and emissions abatement estimates for individual options, where this is appropriate. It should be stressed that for some combinations, this simple assessment methodology will not be suitable as double counting of costs or emissions may occur. The results of this analysis should therefore only be taken as initial indicative results, and they should be used to prioritise option combinations for further, more robust analysis.

2.8.2 Combinations of options for the 2011-2025 and 2025-2050 time periods

As there is a lack of detailed quantitative data for options in the later time periods, a qualitative approach has been taken to developing recommendations for options that could be combined into packages. Again, it is recommended that further, more detailed analysis of proposed option combinations will be necessary.

3 Scenario options for the 2005-2010 time period

3.1 Overview

Details of how the scenarios were developed can be found in Section 2.2. Data on the unit costs and unit emissions benefits associated with individual options were obtained from published literature and industry stakeholders, and are presented in the separate review report (AEAT/ED48300/R01), along with detailed descriptions of each option. The detailed option descriptions are not replicated in this report.

For the 2005-2010 time period, it has been possible to develop relatively detailed hypothetical scenarios based on the assumed deployment of different technical and non-technical options. For each option, a description of the deployment scenario is provided. The assumptions that underpin each deployment scenario have been used in conjunction with the estimated unit capital and operating costs of each option to provide initial assessments of the total capital and operating costs associated with implementing the particular scenario.

For all scenario options considered in the 2005-2010 time period, it has been possible to provide estimates of the total change in UK road transport emissions of NOx and PM_{10} that would occur due to the implementation of the option. For some options, detailed emissions modelling analysis was carried out by Netcen enabling more accurate estimates to be made.

It should be noted that for most of the options that could be implemented between 2005 and 2010, there would also be additional costs and emissions benefits during the 2011-2025 time period. Indeed, for some options that could be implemented between 2005 and 2010, the majority of the emissions benefits will be achieved after 2010 (e.g. emissions reductions associated with the Euro 5 standards). Where appropriate, the future costs and emissions benefits of these options over the 2010-2025 time period have also been assessed but are not presented in this section of the report. Instead, they have been used to contribute to the cost-benefit analysis of these options that can be found in Section 7.4. The following sections set out the different scenarios that have been developed for the 2005-2010 time period.

3.2 Retrofit Selective Catalytic Reduction with Diesel Particulate Filters

3.2.1 Deployment scenario

The assessment of the costs and emissions benefits of retrofitting heavy-duty diesel vehicles with Selective Catalytic Reduction (SCR) technology has been based on assuming that by 2010, 10% of the heavy-duty vehicle fleet (comprising rigid trucks, articulated trucks, and buses) has been fitted with this technology. It has been assumed that SCR equipment would be fitted to vehicles in conjunction with a diesel particulate filter.

3.2.2 Vehicle numbers

Estimated fleet projections from the NAEI indicate that the total number of heavy-duty vehicles is expected to increase by approximately 1% between 2005 and 2010. However, these projections include a 3.5% increase in the number of articulated trucks, a 12.5% increase in the number of buses, but a 4.3% drop in the number of rigid trucks. The projected fleet figures given in Table 3.1 below:

Table 3.1: Projections for the total number of Heavy Duty Vehicles in the UK fleet

	2005	2006	2007	2008	2009	2010
Rigid trucks	303,920	303,297	301,667	298,815	294,941	290,717
Artic trucks	123,040	124,950	126,147	126,726	127,075	127,468
Buses	98,691	101,579	104,477	107,034	109,919	113,200
Total	**525,651**	**529,826**	**532,291**	**532,575**	**531,934**	**531,386**

The take-up rate of SCR technology has been assumed to be linear (an additional 2% of vehicle per year) until 10% of the fleet is equipped with this technology. The technology take-up rate and the estimated number of vehicles equipped with SCR between 2005 and 2010 are presented below in Table 3.2.

Table 3.2: Projected uptake of SCR technology between 2005 and 2010 for this deployment scenario

Year	2005	2006	2007	2008	2009	2010
Percentage of vehicles fitted with SCR	2%	4%	6%	8%	10%	10%
Number of rigid trucks fitted with SCR	6,078	12,132	18,100	23,905	29,494	29,072
Number of artic trucks fitted with SCR	2,461	4,998	7,569	10,138	12,707	12,747
Number of buses fitted with SCR	1,974	4,063	6,269	8,563	10,992	11,320
Total number of heavy duty vehicles fitted with SCR	**10,513**	**21,193**	**31,937**	**42,606**	**53,193**	**53,139**

3.2.3 Implementation costs

There are both capital and operating costs associated with retrofitting SCR technology to heavy-duty vehicles. The capital costs are associated with the SCR equipment itself, whilst the operating costs relate to the requirement for the NOx reducing agent (e.g. urea) to be regularly replenished. Using data for the capital and operating costs of this technology in conjunction with the projections for the total number of vehicles that would be fitted with SCR equipment, it has been possible to provide estimates for the Net Present Value of capital costs and operating costs over the time period 2005 to 2010. This analysis is presented below.

3.2.3.1 Capital costs

Information from industry stakeholders has indicated that the capital costs associated with retrofit SCR technology range from £4,000 to £10,000. The equipment is assumed to have a life-time of eight years and annualised capital costs have been calculated on this basis and are presented below.

Table 3.3: Unit costs of SCR technology

	Total cost	Annualised cost
Unit capital costs (low estimate)	£4,000	£582
Unit capital costs (high estimate)	£10,000	£1,455

Using the projected figures for the penetration of this technology (Table 3.2), the annual capital costs in each year between 2005 and 2010, and the Net Present Value of capital costs over this time period have been estimated (see Table 3.4 and Table 3.5 below).

Table 3.4: Annualised total capital costs to retrofit 10% of the heavy-duty vehicle fleet with SCR+DPF technology by 2010

	2005	**2006**	**2007**	**2008**	**2009**	**2010**
Annualised capital costs in each year (£million) (low estimate)	£6.15	£12.40	£18.67	£24.93	£31.14	£31.12
Annualised capital costs in each year (£million) (high estimate)	£15.38	£31.00	£46.68	£62.32	£77.86	£77.81

Table 3.5: Net Present Value of capital costs between 2005 and 2010 to retrofit 10% of the heavy duty vehicle fleet with SCR+DPF technology

	NPV of capital costs (2005-2010)
Retrofit SCR - low cost estimate	£124.42 million
Retrofit SCR - high cost estimate	£311.05 million

3.2.3.2 Operating costs

The additional operating costs associated with the uptake of SCR technology result from the urea reducing agent. Information obtained from published material and from stakeholder consultation indicates that urea consumption is approximately 6% of fuel consumption; the cost of urea is approximately 37 pence per litre. The average fuel consumption for rigid trucks, articulated trucks, and buses has been estimated using figures for the total annual number of vehicle kilometres travelled by each type of vehicle and the total amount of fuel used annually by each vehicle type[5]; urea consumption for each type of vehicle has been derived from these figures.

Table 3.6: Annual additional operating costs (urea consumption) for those vehicles fitted with SCR+DPF technology

	2005	**2006**	**2007**	**2008**	**2009**	**2010**
Cost of urea consumption (£millions)	£4.53	£9.15	£13.81	£18.48	£23.14	£23.19

Table 3.7: Net Present Value of additional operating costs between 2005 and 2010 for those vehicles retrofitted with SCR+DPF technology

	NPV of operating costs (2005-2010)
Cost of urea consumption	£79.83 million

3.2.4 Emissions abatement performance

Information obtained from industry stakeholder consultation has indicated that fitting SCR technology leads to a reduction in NOx emissions of approximately 65%. It has been assumed that retrofit SCR equipment would be fitted in conjunction with a diesel particulate filter. Such filters lead to a 95% reduction in PM_{10} emissions. The speed dependent vehicle emission factors from the NAEI were modified to take these reductions into account. Estimated reductions in the UK baseline figures for road transport NOx and PM_{10} emissions were then calculated.

It should be noted that depending on the type of diesel particulate filter used in conjunction with the SCR system, there may be an increase in the proportion of NOx emitted as NO_2. As discussed in Section 2.4, CRT particulate filters can lead to significant increases in primary NO_2 emissions.

Table 3.8: Estimated reduction in total NOx emissions from road transport due to the increased uptake of SCR + DPF technology

NOx emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline NOx emissions from road transport	572.20	534.52	495.15	457.12	417.81	384.37	2861.18
Estimate of total road transport NOx emissions with increased uptake of SCR technology	568.74	527.91	485.89	445.69	404.98	372.83	2806.04
Emissions abatement against baseline	**-3.47**	**-6.61**	**-9.26**	**-11.43**	**-12.83**	**-11.54**	**-55.14**
Percentage reduction against baseline	**-0.61%**	**-1.24%**	**-1.87%**	**-2.50%**	**-3.07%**	**-3.00%**	**-1.93%**

Table 3.9: Estimated reduction in total PM_{10} emissions from road transport due to the increased uptake of SCR + DPF technology

PM_{10} emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline PM_{10} emissions from road transport	25.59	24.16	22.40	20.70	19.14	17.83	129.82
Estimate of total road transport PM_{10} emissions with increased uptake of SCR technology	25.47	23.94	22.12	20.38	18.79	17.53	128.22
Emissions abatement against baseline	**-0.12**	**-0.22**	**-0.29**	**-0.33**	**-0.35**	**-0.30**	**-1.60**
Percentage reduction against baseline	**-0.46%**	**-0.91%**	**-1.28%**	**-1.58%**	**-1.82%**	**-1.67%**	**-1.23%**

It has been assumed that SCR technology does not alter the fuel consumption of vehicles, hence there would be no change to CO_2 emissions from SCR-equipped vehicles.

3.2.5 Qualitative assessment of wider impacts

Table 3.10 below provides information on the qualitative scores that have been applied to retrofit SCR technology in relation to all the wider impacts of this option.

Table 3.10: Assessment of the wider impacts of increase uptake of SCR+DPF technology for heavy duty vehicles

Performance criteria	Qualitative score
Carbon monoxide emissions	2
Hydrocarbon emissions	1
Ground level ozone	3
Noise	0
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	-1
Public/industry acceptability	-1
Practicality	-1

3.3 Retrofit Exhaust Gas Recirculation with diesel particulate filter

3.3.1 Deployment scenario

Retrofit Exhaust Gas Recirculation (EGR) is an alternative to SCR technology as a method for reducing NOx emissions from road transport. Light duty vehicles have been fitted with the technology for a number of years, but to date, the technology has not penetrated the heavy-duty market in significant numbers. The scenario that has been developed for this option follows the projected penetration rates discussed for the SCR option; it has been assumed that by 2010, 10% of trucks and buses will have been fitted with EGR equipment. The following sections present the analysis of the costs and emissions abatement performance that would be expected if this scenario occurred.

Projected fleet figures for heavy-duty vehicles have already been presented in Table 3.1. The take-up rate for EGR technology has been assumed to mirror the scenario presented for SCR technology in Table 3.2. Projections for the total number of vehicles that would be equipped with this technology under this scenario are presented below in Table 3.11. It should be noted that EGR technology can only be retrofitted to vehicles equipped with engines that, as a minimum, meet the Euro 2 emissions standards.

Table 3.11: Projected uptake of EGR technology between 2005 and 2010 for this deployment scenario

Year	2005	2006	2007	2008	2009	2010
Percentage of vehicles fitted with EGR	2%	4%	6%	8%	10%	10%
Number of rigid trucks fitted with EGR	6,078	12,132	18,100	23,905	29,494	29,072
Number of artic trucks fitted with EGR	2,461	4,998	7,569	10,138	12,707	12,747
Number of buses fitted with EGR	1,974	4,063	6,269	8,563	10,992	11,320
Total number of heavy duty vehicles fitted with EGR	**10,513**	**21,193**	**31,937**	**42,606**	**53,193**	**53,139**

3.3.2 Implementation costs

.

3.3.2.1 Capital costs

The unit costs associated with retrofit EGR equipment range from £3,500 to £10,000. As with SCR, these costs have been annualised over an eight-year lifetime (see Table 3.12 below). Low and high estimates for the annualised costs of retrofitting 10% of the heavy-duty vehicle fleet have been prepared based on these figures (see Table 3.13). Estimates for the Net Present Value of these capital costs between 2005 and 2010 are presented in Table 3.14.

Table 3.12: Units costs of EGR technology

	Total cost	Annualised cost
Unit capital costs (low estimate)	£3,500	£509.17
Unit capital costs (high estimate)	£10,000	£1,454.77

Table 3.13: Annualised total capital costs to retrofit 10% of the heavy duty vehicle fleet with EGR technology by 2010

	2005	2006	2007	2008	2009	2010
Annualised capital costs in each year (£million) (low estimate)	£5.38	£10.85	£16.34	£21.81	£27.25	£27.23
Annualised capital costs in each year (£million) (high estimate)	£15.38	£31.00	£46.68	£62.32	£77.86	£77.81

Table 3.14: Net Present Value of capital costs between 2005 and 2010 to retrofit 10% of the heavy duty vehicle fleet with EGR technology

	NPV of capital costs (2005-2010)
Retrofit EGR - low cost estimate	£108.87 million
Retrofit EGR - high cost estimate	£311.05 million

3.3.2.2 Operating costs

Additional operating costs would be incurred from the addition of EGR equipment, as there is typically a 2% increase in fuel consumption associated with this technology. Estimates for the additional operating costs due to this increase in fuel consumption have been made for each year between 2005 and 2010 and are presented below in Table 3.15 and Table 3.16.

Table 3.15: Annual additional operating costs for those vehicles retrofitted with EGR technology

	2005	2006	2007	2008	2009	2010
Cost of additional fuel (£millions)	£3.15	£6.35	£9.57	£12.77	£15.95	£15.93

Table 3.16: Net Present Value of additional operating costs between 2005 and 2010 for those vehicles retrofitted with EGR technology

	NPV of operating costs (2005-2010)
Cost of additional fuel	£55.13 million

3.3.3 Emissions abatement performance

The addition of EGR technology leads to an estimated 45% reduction in NOx emissions, and a 95% reduction in PM_{10} emissions (due to the inclusion of a diesel particulate filter). Using these figures, the impact on UK road transport NOx and PM_{10} emissions of increasing the proportion of heavy-duty vehicles equipped with EGR + DPF to 10% by 2010 has been estimated and is presented below in Table 3.17 and

Table 3.18.

In the same manner as for SCR systems, it should be noted that if a CRT diesel particulate filter is used in conjunction with the EGR system, there may be an increase in the proportion of NOx emitted as NO_2.

Table 3.17: Estimated reduction in total NOx emissions from road transport due to the increased uptake of EGR + DPF technology

NOx emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total NOx emissions from road transport	572.20	534.52	495.15	457.12	417.81	384.37	2861.18
Estimated total NOx emissions with increased uptake of EGR technology	569.80	529.95	488.74	449.20	408.93	376.38	2823.01
Emissions abatement against baseline	**-2.40**	**-4.57**	**-6.41**	**-7.91**	**-8.88**	**-7.99**	**-38.17**
Percentage reduction against baseline	**-0.42%**	**-0.86%**	**-1.29%**	**-1.73%**	**-2.13%**	**-2.08%**	**-1.33%**

Table 3.18: Estimated reduction in total PM_{10} emissions from road transport due to the increased uptake of EGR + DPF technology

PM_{10} emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total PM_{10} emissions from road transport	25.59	24.16	22.40	20.70	19.14	17.83	129.82
Estimated total PM_{10} emissions with increased uptake of EGR technology	25.47	23.94	22.12	20.38	18.79	17.53	128.22
Emissions abatement against baseline	**-0.12**	**-0.22**	**-0.29**	**-0.33**	**-0.35**	**-0.30**	**-1.60**
Percentage reduction against baseline	**-0.46%**	**-0.91%**	**-1.28%**	**-1.58%**	**-1.82%**	**-1.67%**	**-1.23%**

Due to the 2% increase in fuel consumption associated with EGR, there would be an associated 2% increase in CO_2 emissions from vehicles equipped with this technology. Table 3.19 below provides estimates of the likely annual increases in CO_2 emissions between 2005 and 2010 associated with this scenario option.

Table 3.19: Estimated increase in total CO_2 emissions from road transport due to the increased uptake of EGR + DPF technology

CO_2 emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Estimated change in CO_2 emissions due to uptake of EGR technology	+10.76	+21.76	+32.85	+43.94	+55.03	+55.14	+219.49

3.3.4 Qualitative assessment of wider impacts

The assessment of the wider impacts of EGR + DPF technology is presented in Table 3.20.

Table 3.20: Assessment of the wider impacts of increased uptake of EGR+DPF technology for heavy-duty vehicles

Performance criteria	Qualitative score
Carbon monoxide emissions	2
Hydrocarbon emissions	2
Ground level ozone	2
Noise	0
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	-1
Public/industry acceptability	-1
Practicality	-1

3.4 Increased uptake of Compressed Natural Gas heavy duty vehicles

3.4.1 Deployment scenario

Estimates for the costs and emissions benefits of increased uptake of Compressed Natural Gas (CNG) heavy duty vehicles have been provided for a scenario where 2% of trucks and buses are equipped with CNG engines by 2010. Based on the estimated projections for total numbers of trucks and buses that are likely to be on UK roads between 2005 and 2010, estimates for the number of CNG equipped vehicles in each year have been made and are presented in Table 3.21 below.

Table 3.21: Projected uptake of CNG technology between 2005 and 2010 for this deployment scenario

Year	2005	2006	2007	2008	2009	2010
Percentage of vehicles retrofitted with CNG	0.2%	0.4%	0.8%	1.2%	1.6%	2.0%
Number of rigid trucks fitted with CNG engines	608	1,213	2,413	3,586	4,719	5,814
Number of artic trucks fitted with CNG engines	246	500	1,009	1,521	2,033	2,549
Number of buses fitted with CNG engines	197	406	836	1,284	1,759	2,264
Total number of heavy duty vehicle sfitted with CNG engines	**1,051**	**2,119**	**4,258**	**6,391**	**8,511**	**10,628**

3.4.2 Implementation costs

3.4.2.1 Capital costs
The implementation costs have been based on the estimated costs for retrofitting heavy-duty vehicles with CNG engines. Data obtained from industry stakeholders indicates that typical costs are in the region of £20,000 per vehicle. These costs have been annualised on the basis that the average life-time of the vehicle and equipment following retrofitting will be eight years.

Table 3.22: Units costs of retrofit CNG engines for heavy duty vehicles

	Total cost per unit	Annualised cost
Unit capital costs	£20,000	£2,910

Based on the deployment scenario described above, and using the annualised unit capital costs given in Table 3.22, estimates for the total annualised capital costs of this option in each year between 2005 and 2010 have been calculated and are presented below in Table 3.23. The estimated Net Present Value of capital costs between 2005 and 2010 is presented in Table 3.24.

Table 3.23: Annualised capital costs associated with retrofitting 2% of the heavy duty vehicle fleet with CNG engines by 2010

	2005	2006	2007	2008	2009	2010
Annualised capital costs in each year (£millions)	£3.08	£6.20	£12.45	£18.70	£24.92	£31.12

Table 3.24: Net Present Value of capital costs between 2005 and 2010 to retrofit 2% of the heavy duty vehicle fleet with CNG engines

	NPV of capital costs (2005-2010)
Retrofit CNG for heavy duty vehicles	£96.46 million

3.4.2.2 Operating costs
It should be noted that unlike conventional diesel fuel, CNG fuel consumption and costs are typically quoted in terms of km/kg and pence per kg respectively. In order to compare the fuel costs of diesel and CNG vehicles, it has been necessary to convert the fuel costs into costs per km travelled. Furthermore, it has been necessary to take into account the differences between fuel costs for trucks and buses. Unlike trucks operators, bus operators receive a rebate on the fuel duty that they pay, through the Bus Service Operators Grant. Currently, for diesel fuel, the rebate is 80% of the duty, whilst for road gas fuels, the rebate is 100%. However, the current duty rates for the two types of fuel are very different; road diesel is subject to a fuel duty of 47.1 pence per litre, whilst CNG (and all other road fuel gases) incur duty costs of 9.0 pence per kg.

Table 3.25: Comparison of fuel consumption for diesel and CNG-powered vehicles

Vehicle type	Diesel (litres per km)	CNG (kg per km)
Rigid truck	0.34	0.41
Articulated truck	0.38	0.42
Bus	0.28	0.40

Table 3.26: Comparison of fuel costs for diesel and CNG vehicles

	Diesel (£/litre)	CNG (£/kg)
Trucks	£0.85	£0.51
Buses	£0.41	£0.40

Table 3.27: Comparison of fuel costs (cost per kilometre travelled) for diesel and CNG vehicles

	Diesel (£/km)	CNG (£/km)
Rigid trucks	£0.29	£0.21
Articulated trucks	£0.32	£0.21
Buses	£0.11	£0.16

As can be seen from the figures in the above tables, although CNG fuel costs (cost per km) are lower for rigid and articulated trucks, they have been estimated to be higher for buses, due to the Bus Service Operators Grant.

Estimates for the change in fuel costs in each year between 2005 and 2010 for the deployment scenario have been calculated. These costs are presented below in Table 3.28.

Table 3.28: Annual total change in operating costs for all vehicles retrofitted with CNG engines

	Change in fuel costs (£million)					
	2005	**2006**	**2007**	**2008**	**2009**	**2010**
Rigid trucks	-£1.89	-£3.76	-£7.49	-£11.13	-£14.64	-£18.04
Articulated trucks	-£2.55	-£5.17	-£10.44	-£15.74	-£21.04	-£26.38
Buses	£0.64	£1.32	£2.71	£4.17	£5.73	£7.38
Total change in operating costs	**-£3.79**	**-£7.61**	**-£15.22**	**-£22.69**	**-£29.95**	**-£37.03**

Table 3.29: Net Present Value of reduction in operating costs between 2005 and 2010 for those vehicles retrofitted with CNG engines

	NPV of operating costs (2005-2010)
Estimated change in fuel costs	-£99.61 million

3.4.3 Emissions abatement performance

Estimates of the reduction in total road transport emissions that would result from increased uptake of CNG vehicles have been based on assuming that a CNG powered vehicle emits 80% less NOx and 95% less PM_{10} than an equivalent Euro 3 vehicle. CO_2 emissions, on the other hand, increase by 5%. Table 3.30, Table 3.31, and Table 3.32 present the results of the emissions modelling for this option.

Table 3.30: Estimated reduction in total NOx emissions from road transport due to the increased uptake of CNG-powered vehicles

NOx emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total NOx emissions from road transport	572.20	534.52	495.15	457.12	417.81	384.37	2861.18
Estimated total NOx emissions with increased uptake of CNG vehicles	569.80	529.95	488.74	449.20	408.93	376.38	2823.01
Emissions abatement against baseline	**-2.40**	**-4.57**	**-6.41**	**-7.91**	**-8.88**	**-7.99**	**-38.17**
Percentage reduction against baseline	**-0.42%**	**-0.86%**	**-1.29%**	**-1.73%**	**-2.13%**	**-2.08%**	**-1.33%**

Table 3.31: Estimated reduction in total PM_{10} emissions from road transport due to the increased uptake of CNG-powered vehicles

PM_{10} emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total PM_{10} emissions from road transport	25.59	24.16	22.40	20.70	19.14	17.83	129.82
Estimated total PM_{10} emissions with increased uptake of CNG vehicles	25.47	23.94	22.12	20.38	18.79	17.53	128.22
Emissions abatement against baseline	**-0.12**	**-0.22**	**-0.29**	**-0.33**	**-0.35**	**-0.30**	**-1.60**
Percentage reduction against baseline	**-0.46%**	**-0.91%**	**-1.28%**	**-1.58%**	**-1.82%**	**-1.67%**	**-1.23%**

Table 3.32: Estimated increase in total CO_2 emissions from road transport due to the increased uptake of CNG-powered vehicles

CO_2 emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Estimated change in CO_2 emissions due to uptake of CNG vehicles	+56.50	+114.23	+229.95	+346.06	+462.29	+578.99	+1788.02

3.4.4 Qualitative assessment of wider impacts

An assessment of the wider impacts of increased uptake of CNG-powered vehicles is provided in Table 3.33.

Table 3.33: Assessment of the wider impacts of increased uptake of CNG-powered vehicles

Performance criteria	Qualitative score
Carbon monoxide emissions	2
Hydrocarbon emissions	2
Ground level ozone	3
Noise	2
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	-3
Public/industry acceptability	-2
Practicality	-3

3.5 Uptake of Euro 5 emission standards for light duty vehicles

3.5.1 Deployment scenario

Euro 5 emission standards for light duty vehicles are likely to come into force from 2010, and whilst a final decision on what form these standards will take has not yet been made, a number of the possible options have been assessed by the Department for Transport, and a shortlist of scenario options to be taken forward has been developed. The scenario that has been assessed for this study is referred to as “DfT Scenario C”. Table 3.34 below presents the emission limits for this scenario, along with the Euro 4 limit values for comparison purposes.

Table 3.34: Comparison NOx and PM10 emission limits for Euro 4 and one of the scenarios proposed for Euro 5 (DfT scenario C)

Emission factors (g/km)				
Vehicle Type	**Euro 4**		**Euro 5 Scenario C**	
	NO_x	PM_{10}	NO_x	PM_{10}
Petrol Car	80	-	80	5 (DI)
Petrol Van (Class I)	80	-	80	5 (DI)
Petrol Van (Class II)	100	-	100	5 (DI)
Petrol Van (Class III)	110	-	110	5 (DI)
Diesel Car	250	25	125	5
Diesel Van (Class I)	250	25	125	5
Diesel Van (Class II)	330	60	165	5
Diesel Van (Class III)	390	60	195	5

*DI refers to Direct Injection petrol engines

3.5.2 Implementation costs

3.5.2.1 Capital costs

As Euro 5 is not likely to come into force until 2010, the implementation costs will be limited during the 2005-2010 time period (and in fact the majority of costs and emissions benefits will accrue during the period between 2011 and 2025). However, estimates for the likely costs during the earlier time period have been made, on the basis of the abatement equipment that will be required for different types of vehicles, and the costs associated with increased fuel consumption for some vehicles.

Estimates of the additional unit capital costs for both petrol and diesel vehicles are presented below[11], based on the application of Diesel Particulate Filters (DPFs) and de-NOx exhaust after-treatment for all diesel vehicles, and changes to engine control technology for petrol vehicles. Total unit costs have been annualised using average life times of 12 years for passenger cars, and 11 years for light goods vehicles.

Table 3.35: Additional unit costs associated with Euro 5 light duty standards (DfT scenario C)

	Total unit cost	Annualised cost
Conventional petrol car	£0	£0.00
GDI petrol car	£93	£9.62
Petrol vans	£0	£0.00
Diesel car	£300	£31.05
Small diesel van	£300	£33.33
Medium/large diesel van	£540	£59.99

Estimates of the total annualised costs of ensuring that all new cars and light goods vehicles meet the Euro 5 standard in 2010 are presented below in Table 3.36, and the Net Present Value of these capital costs is presented in Table 3.37.

Table 3.36: Annualised total capital costs associated with all new light duty vehicles meeting Euro 5 emissions standards from 2010 onwards

Annualised capital costs (£millions)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Conventional petrol cars	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00
GDI petrol cars	£0.00	£0.00	£0.00	£0.00	£0.00	£0.78
Petrol vans	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00
Diesel cars	£0.00	£0.00	£0.00	£0.00	£0.00	£36.30
Small diesel vans	£0.00	£0.00	£0.00	£0.00	£0.00	£3.16
Medium/large diesel vans	£0.00	£0.00	£0.00	£0.00	£0.00	£12.68
TOTAL	**£0.00**	**£0.00**	**£0.00**	**£0.00**	**£0.00**	**£52.92**

Table 3.37: Net Present Value of capital costs between 2005 and 2010 associated with ensuring that new light duty vehicles meet the Euro 5 emissions standards

	NPV of capital costs (2005-2010)
Euro 5 capital costs	£52.92 million

3.5.2.2 Operating costs

Additional operating costs for Euro 5 vehicles are wholly due to the increased fuel consumption associated with diesel vehicles fitted with a combination of DPFs and de-NOx exhaust after-treatment equipment; it has been estimated that light duty vehicles fitted with DPFs use an average of 2% more fuel, whilst DPFs used in conjunction with de-NOx equipment are estimated to lead to a 5% increase in fuel consumption[11]. However, the impact on diesel fuel consumption of this combination of equipment is not fully characterised, and hence the 5% fuel consumption penalty should be treated as a conservative estimate until further work can be carried out to provide a greater level of detail. Based on this figure it has been possible to estimate the total volume of additional fuel that would be used by all Euro 5 vehicles in 2010, and the costs associated with this. These additional annual costs and the Net Present Value of additional operating costs between 2005 and 2010 are presented below in Table 3.38 and Table 3.39.

Table 3.38: Additional annual operating costs associated with Euro 5 light duty vehicles

Annual operating costs (£millions)	2005	2006	2007	2008	2009	2010
Diesel cars	£0.00	£0.00	£0.00	£0.00	£0.00	£74.06
Small diesel vans	£0.00	£0.00	£0.00	£0.00	£0.00	£7.12
Medium/large diesel var	£0.00	£0.00	£0.00	£0.00	£0.00	£15.85
TOTAL	**£0.00**	**£0.00**	**£0.00**	**£0.00**	**£0.00**	**£97.03**

Table 3.39: Net Present Value of additional annual operating costs (2005-2010) for Euro 5 light duty vehicles

	NPV of operating costs (2005-2010)
Cost of additional fuel	£93.75 million

3.5.3 Emissions abatement performance

Using the proposed emission standards for DfT's Euro 5 Scenario C, it has been possible to estimate the likely emissions benefits that would accrue from the implementation of the Euro 5 standard for light duty vehicles. As noted above, the emissions benefits that would be observed in the 2005-2010 time period will be limited as the standard will not come into force before 2010, and hence the most significant benefits will be achieved after 2010 (further analysis of the likely benefits during the 2011-2025 time period is presented in Section 7.4).

Table 3.40: Estimated reduction in total NOx emissions from road transport due to the introduction of Euro 5 light duty emission standards

NOx emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total NOx emissions from road transport	572.20	534.52	495.15	457.12	417.81	384.37	2861.18
Estimated total NOx emissions with Euro 5 (Scenario C) for light duty vehicles in place from 2010	572.20	534.52	495.15	457.12	417.81	373.44	2850.25
Emissions abatement against baseline	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**-10.93**	**-10.93**
Percentage reduction against baseline	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**-2.84%**	**-0.38%**

Table 3.41: Estimated reduction in total PM_{10} emissions from road transport due to the introduction of Euro 5 light duty emission standards

PM_{10} emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total PM_{10} emissions from road transport	25.59	24.16	22.40	20.70	19.14	17.83	129.82
Estimated total PM_{10} emissions with Euro 5 (Scenario C) for light duty vehicles in place from 2010	25.59	24.16	22.40	20.70	19.14	16.86	128.85
Emissions abatement against baseline	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**-0.97**	**-0.97**
Percentage reduction against baseline	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**-5.42%**	**-0.75%**

Table 3.42: Estimated change in total CO_2 emissions from road transport due to the introduction of Euro 5 light duty emission standards

CO_2 emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Estimated change in CO_2 emissions due to introduction of Euro 5 for light duty vehicles	0.00	0.00	0.00	0.00	0.00	+301.31	+301.31

It should be noted that for Euro 5 diesel vehicles, depending on the type of DPF used, there may be increases in the proportion of NOx emitted as NO_2. As discussed in Section 2.4, CRT filters can lead to increased primary NO_2 emissions, with a consequent detrimental effect on NO_2 concentrations. More detailed analysis would be required to understand the likely impact on primary NO_2 emissions of using a combination of CRT filter with NOx adsorber catalyst.

3.5.4 Qualitative assessment of wider impacts

Table 3.43: Assessment of the wider impacts of the introduction of Euro 5 light duty emission standards

Performance criteria	Qualitative score
Carbon monoxide emissions	0
Hydrocarbon emissions	0
Ground level ozone	1
Noise	0
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	0
Public/industry acceptability	0
Practicality	-1

3.6 Low emission passenger cars

3.6.1 Deployment scenarios

Low emission vehicles encompass a range of technologies including hybrid-electric passenger cars and options based on conventional internal combustion engine technology coupled with exhaust after-treatment systems such as particulate traps and De-NOx systems.

As this option covers a range of different technologies (each of which will have a different abatement performance), an assumption has had to be made with regard to the likely average reductions in NOx and PM_{10} emissions from the range of low emission vehicles that could be available and between 2005 and 2010. The estimated average emissions abatement performance figures (compared to Euro 4 vehicles) used in the modelling for this option are presented in Table 3.44 below, and are heavily based on emissions modelling work that Netcen carried out in 2004 to examine the emissions abatement performance of hybrid passenger cars. For this reason, it should be noted that the assumed emissions abatement performance used here may be optimistic if low emission vehicles use exhaust after-treatment options in preference to hybrid-electric technology.

Table 3.44: Estimated percentage reduction in NOx and PM_{10} emissions for low emission passenger cars

	Percentage reduction in emissions compared to average Euro 4 passenger car	
	NOx	**PM_{10}**
Petrol car	72%	73%
Diesel car	91%	87%

This scenario assumes that the proportion of new cars classed as low emission vehicles increases by 2010. Two scenarios (low uptake and high uptake) have been examined for low emission vehicles. For the low uptake scenario, it has been assumed that by 2010, 10% of new cars sales would be equipped with low emission technology. The high uptake scenario assumes that over the same time scale, low emission cars account for 40% of new car sales. The projected numbers of low emission passenger cars sold in each year between 2005 and 2010 for these two scenarios are presented below in Table 3.45 and Table 3.46.

Table 3.45: Projected sales of low emission passenger cars (10% of new car sales of by 2010)

	2005	2006	2007	2008	2009	2010
Projected sales of passenger cars	2,547,016	2,534,628	2,587,768	2,655,598	2,721,809	2,783,781
Projected sales of low emission passenger cars as a percentage of all car sales	0%	2%	4%	6%	8%	10%
Projected sales of low emission passenger cars	0	50,693	103,511	159,336	217,745	278,378

Table 3.46: Projected sales of low emission passenger cars (40% of new car sales by 2010)

	2005	2006	2007	2008	2009	2010
Projected sales of passenger cars	2,547,016	2,534,628	2,587,768	2,655,598	2,721,809	2,783,781
Projected sales of low emission passenger cars as a percentage of all car sales	0%	5%	10%	18%	28%	40%
Projected sales of low emission passenger cars	0	126,731	258,777	478,008	762,107	1,113,512

3.6.2 Implementation costs

3.6.2.1 Capital costs

The additional capital costs associated with this option are related to the higher costs of vehicles equipped with low emission and hybrid technology. For example, the purchase prices of hybrid cars are currently between £1,500 and £2,000 greater than the price of a conventional petrol or diesel car. In calculating the annual costs associated with the uptake of hybrid technology, these additional costs have been annualised over a twelve-year time period, reflecting the average lifetime of a passenger car in the UK. It should be stressed that further work will be required to separately characterise the additional capital costs associated with different types of low emission passenger car.

Table 3.47: Additional unit costs of low emission passenger cars

	Total cost	Annualised cost
Unit capital costs (low estimate)	£1,500	£155.23
Unit capital costs (high estimate)	£2,000	£206.97

Estimates of the annual capital costs for the two deployment scenarios (using both low and high cost estimates), along with estimates of the net present value of capital costs between 2005 and 2010 are presented in the tables below.

Table 3.48: Annualised capital costs for low emission passenger car scenario: 10% uptake of new car sales by 2010

	2005	2006	2007	2008	2009	2010
Annualised capital costs in each year (£million) (low estimate)	£0.00	£7.87	£23.94	£48.67	£82.47	£125.68
Annualised capital costs in each year (£million) (high estimate)	£0.00	£10.49	£31.92	£64.89	£109.96	£167.57

Table 3.49: Annualised capital costs for low emission passenger car scenario: 40% uptake of new car sales by 2010

	2005	2006	2007	2008	2009	2010
Annualised capital costs in each year (£million) (low estimate)	£0.00	£19.67	£59.84	£134.04	£252.34	£425.18
Annualised capital costs in each year (£million) (high estimate)	£0.00	£26.23	£79.79	£178.72	£336.45	£566.91

Table 3.50: Net Present Value of additional capital costs associated with increased uptake of low emission passenger cars between 2005 and 2010 (10% of new car sales by 2010)

	NPV of capital costs (2005-2010)
Low emission passenger cars (10% of new sales) (low cost estimate)	£288.62 million
Low emission passenger cars (10% of new sales) (high cost estimate)	£384.83 million

Table 3.51: Net Present Value of additional capital costs associated with low emission passenger cars between 2005 and 2010 (40% of new car sales by 2010)

	NPV of capital costs (2005-2010)
Low emission passenger cars (40% of new sales) (low cost estimate)	£891.08 million
Low emission passenger cars (40% of new sales) (high cost estimate)	£1,188.10 million

3.6.2.2 Operating costs

Low emission passenger cars may have lower operating costs than conventional petrol and diesel vehicles due to reduced fuel consumption. In particular, there are significant reductions in fuel consumption for hybrid passenger cars. Estimates of the reduction in fuel costs that could be achieved have been based on assuming that, on average, low emission passenger cars use 30% less fuel than equivalent conventional passenger cars. Projected fuel cost savings for both the 10% deployment scenario and the 40% deployment scenario are presented in the following tables. It must be stressed that further work in this area will be required to separately characterise changes in operating costs associated with the uptake different types of low emission passenger cars.

Table 3.52: Annual reduction in operating costs for low emission cars due to reduced fuel consumption (10% uptake of new car sales by 2010)

	2005	2006	2007	2008	2009	2010
Fuel cost savings	£0.00	-£16.20	-£49.28	-£100.20	-£169.79	-£258.75

Table 3.53: Annual reduction in operating costs for low emission cars due to reduced fuel consumption (40% uptake of new car sales by 2010)

	2005	2006	2007	2008	2009	2010
Fuel cost savings	£0.00	-£40.50	-£123.20	-£275.96	-£519.51	-£875.37

Table 3.54: Net Present Value of the reduction in operating costs between 2005 and 2010 (10% uptake of new car sales by 2010)

	NPV of operating costs (2005-2010)
Total fuel savings	-£500.34 million

Table 3.55: Net Present Value of the reduction in operating costs between 2005 and 2010 (40% uptake of new car sales by 2010)

	NPV of operating costs (2005-2010)
Total fuel savings	-£1,538.94 million

3.6.3 Emissions abatement performance

The emissions abatement performance of low emission passenger cars has been estimated using the percentage abatement figures presented in Table 3.44. CO_2 emissions have been assumed to be 30% lower than a conventional Euro 4 passenger car (based on an estimated 30% reduction in fuel consumption for hybrid cars). Using these figures, a modified set of speed dependent vehicle emission factors from the National Atmospheric Emissions Inventory have been used to estimate the effects of the two uptake scenarios on total vehicle emissions in each year between 2005 and 2010. As with the cost data, it should be emphasised that further work will be required to fully characterise the emissions abatement performance of different types of low emission passenger cars, and hence the data presented in the following sections should be viewed as initial estimates.

3.6.3.1 Low uptake scenario (10% of new car sales by 2010)

Table 3.56 and Table 3.57 provide data on the potential reduction in NOx and PM_{10} emissions if the percentage of new car sales that are low emission vehicles were to reach 10% by 2010. The effect on CO_2 emissions is presented in Table 3.58.

Table 3.56: Estimated reduction in total NOx emissions from road transport due to the increased uptake of low emission passenger cars (low uptake scenario: 10% of new car sales by 2010)

NOx emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total NOx emissions from road transport	572.20	534.52	495.15	457.12	417.81	384.37	2861.18
Estimated total NOx emissions with increased low emission cars (low uptake scenario)	572.20	534.34	494.61	455.99	415.87	381.40	2854.40
Emissions abatement against baseline	**0.00**	**-0.18**	**-0.54**	**-1.13**	**-1.95**	**-2.97**	**-6.77**
Percentage reduction against baseline	**0.00%**	**-0.03%**	**-0.11%**	**-0.25%**	**-0.47%**	**-0.77%**	**-0.24%**

Table 3.57: Estimated reduction in total PM_{10} emissions from road transport due to the increased uptake of low emission passenger cars (low uptake scenario: 10% of new car sales by 2010)

PM_{10} emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total PM_{10} emissions from road transport	25.59	24.16	22.40	20.70	19.14	17.83	129.82
Estimated total PM_{10} emissions with increased uptake of low emission cars (low uptake scenario)	25.59	24.15	22.38	20.66	19.06	17.71	129.55
Emissions abatement against baseline	**0.00**	**-0.01**	**-0.02**	**-0.04**	**-0.08**	**-0.12**	**-0.27**
Percentage reduction against baseline	**0.00%**	**-0.03%**	**-0.09%**	**-0.21%**	**-0.40%**	**-0.67%**	**-0.21%**

Table 3.58: Estimated reduction in total CO_2 emissions from road transport due to the increased uptake of low emission passenger cars (low uptake scenario: 10% of new car sales by 2010)

CO_2 emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Estimated change in CO_2 emissions due to uptake of low emission cars (low uptake scenario)	-47.54	-142.17	-287.09	-485.37	-739.41	-999.23	-2700.81

3.6.3.2 High uptake scenario

Table 3.59 and Table 3.60 provide data on the potential reduction in NOx and PM_{10} emissions if the percentage of new car sales that are low emission vehicles were to reach 40% by 2010. The impact of this scenario on CO_2 emissions is presented in Table 3.61.

Table 3.59: Estimated reduction in total NOx emissions from road transport due to the increased uptake of low emission passenger cars (high uptake scenario: 40% of new car sales by 2010)

NOx emissions (kilotonnes)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total (2005-2010)**
Baseline total NOx emissions from road transport	572.20	534.52	495.15	457.12	417.81	384.37	2861.18
Estimated total NOx emissions with increased uptake of low emission cars (high uptake scenario)	572.20	533.79	492.99	452.60	410.02	372.48	2834.08
Emissions abatement against baseline	**0.00**	**-0.73**	**-2.16**	**-4.52**	**-7.79**	**-11.89**	**-27.10**
Percentage reduction against baseline	**0.00%**	**-0.14%**	**-0.44%**	**-0.99%**	**-1.87%**	**-3.09%**	**-0.95%**

Table 3.60: Estimated reduction in total PM_{10} emissions from road transport due to the increased uptake of low emission passenger cars (high uptake scenario: 40% of new car sales by 2010)

PM_{10} emissions (kilotonnes)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total (2005-2010)**
Baseline total PM_{10} emissions from road transport	25.59	24.16	22.40	20.70	19.14	17.83	129.82
Estimated total PM_{10} emissions with increased uptake of low emission cars (high uptake scenario)	25.59	24.13	22.32	20.53	18.83	17.35	128.75
Emissions abatement against baseline	**0.00**	**-0.03**	**-0.08**	**-0.18**	**-0.31**	**-0.47**	**-1.07**
Percentage reduction against baseline	**0.00%**	**-0.13%**	**-0.38%**	**-0.85%**	**-1.61%**	**-2.66%**	**-0.83%**

Table 3.61: Estimated reduction in total CO_2 emissions from road transport due to the increased uptake of low emission passenger cars (high uptake scenario: 40% of new car sales by 2010)

CO_2 emissions (kilotonnes)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total (2005-2010)**
Estimated change in CO_2 emissions due to uptake of low emission cars (high uptake scenario)	-47.54	-165.83	-407.35	-853.50	-1564.80	-2604.08	-5643.10

3.6.4 Qualitative assessment of wider impacts

Table 3.62 and Table 3.63 give details of the assessments of the wider impacts of the two scenarios for the uptake of low emission passenger cars.

Table 3.62: Assessment of wider impacts for low uptake scenario

Performance criteria	Qualitative score
Carbon monoxide emissions	2
Hydrocarbon emissions	2
Ground level ozone	1
Noise	1
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	0
Public/industry acceptability	1
Practicality	1

Table 3.63: Assessment of wider impacts for high uptake scenario

Performance criteria	Qualitative score
Carbon monoxide emissions	3
Hydrocarbon emissions	3
Ground level ozone	3
Noise	1
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	0
Public/industry acceptability	1
Practicality	-2

3.7 Hybrid buses

3.7.1 Deployment scenarios

In a similar manner to hybrid passenger cars, hybrid diesel-electric buses offer the possibilities of improved emissions performance coupled with reduced fuel consumption. It should be noted that there are two types of hybrid bus technology; low carbon hybrid technology where the major benefits are reductions in fuel consumption and CO_2 emissions, and low NOx/PM_{10} hybrid technology where there is no reduction in CO_2 emissions or fuel consumption, but much greater reductions in NOx and PM_{10} emissions are possible. The cost implications and emissions abatement performance of each of these two options have been assessed separately within this section.

The deployment scenario used assumes that by 2010, 2% of the bus fleet is equipped with hybrid technology. Table 3.64 below provides estimates for the projected total number of buses in the UK between 2005 and 2010, along with estimates for this scenario of the number of hybrid buses in each year over the same time period.

Table 3.64: Projected uptake of hybrid buses for this scenario

	2005	2006	2007	2008	2009	2010
Projected numbers of vehicles in the bus fleet	101,579	104,477	107,034	109,919	113,200	116,690
Projected number of hybrid buses as a proportion of all buses	0.2%	0.4%	0.8%	1.2%	1.6%	2.0%
Projected numbers of hybrid buses	203	418	856	1,319	1,811	2,334

3.7.2 Implementation costs

3.7.2.1 Capital costs

It has been estimated that the typical additional costs of a hybrid bus are in the region of £75,000 per unit. The additional capital costs have been annualised over a 15-year time period, giving an annualised cost of £6,512. Using this figure, the annual and net present value of capital costs associated with achieving 2% penetration of the bus fleet by 2010 have been estimated (see Table 3.66 and Table 3.67). The additional capital costs for low-carbon hybrids and low-NOx/PM_{10} hybrids have been assumed to be the same.

Table 3.65: Unit additional costs associated with hybrid buses

	Total cost per unit	Annualised cost
Capital costs	£75,000	£6,512

Table 3.66: Annual capital costs associated with the uptake of hybrid buses

	2005	2006	2007	2008	2009	2010
Annualised capital costs in each year (£million)	£1.32	£2.72	£5.58	£8.59	£11.79	£15.20

Table 3.67: Net Present Value of capital costs incurred between 2005 and 2010 associated with the uptake of hybrid buses

	NPV of capital costs (2005-2010)
Hybrid buses	£45.20 million

3.7.2.2 Operating costs

Changes in operating costs are dependent on the type of hybrid bus; for low-NOx/PM_{10} hybrids, there are no improvements in fuel consumption, and hence operating costs will remain broadly the same as for conventional buses. For low-carbon hybrid buses, a 30% reduction in fuel consumption can be expected, with an associated reduction in fuel costs. The following presents an assessment of the total reduction in fuel costs that could be expected between 2005 and 2010 due to the uptake of low carbon hybrid buses.

The average fuel consumption of a diesel bus has been estimated using information from the NAEI concerning the total fuel used by buses in the UK annually, and the total number of kilometres travelled in the UK by buses annually. The most recent year for which data are available is 2002. Using this data, it has been estimated that the average fuel consumption of a diesel bus is 0.278 litres per km. Low-carbon hybrid buses would be expected to use 30% less fuel than the equivalent conventional diesel bus, giving an estimated fuel consumption of 0.195 litres per km. Fuel costs have been calculated assuming a retail price of 85 pence per litre, but also taking into account the Bus Service Operators Grant, which provides bus operators with a rebate of 80% of the duty charged on road diesel. Fuel duty for Ultra Low Sulphur Diesel is currently 47.1 pence per litre and it has been assumed that this does not change between 2005 and 2010. Bus operators are entitled to claim 37.7 pence per litre of fuel.

Table 3.68: Comparison of fuel consumption figures for a conventional diesel bus and a low carbon hybrid bus

	Fuel consumption (litres/km)
Diesel bus	0.278
Hybrid diesel-electric bus	0.195

Projections from the NAEI indicate that total annual bus vehicle kilometres travelled in the UK are expected to rise from 5.40 billion kilometres in 2005, to 5.67 billion kilometres in 2010. It has been assumed that the number of kilometres travelled by hybrid buses will be in proportion to their numbers on the road (e.g. in 2010, if 2% of the bus fleet is equipped with hybrid technology, then it is anticipated that 2% of the total distance travelled by buses will be by hybrid buses). Estimates for total number of kilometres travelled by all buses and by hybrid buses are presented in Table 3.69.

Table 3.69: Projected number of vehicle kilometres travelled by hybrid buses for this scenario

	2005	2006	2007	2008	2009	2010
Projected total number of kilometres travelled by all buses in the UK (million vehicle kilometres)	5,401.5	5,454.4	5,507.3	5,560.4	5,613.4	5,666.4
Projected percentage of buses equipped with hybrid technology	0.20%	0.40%	0.80%	1.20%	1.60%	2.00%
Projected number of kilometres travelled by hybrid buses (million vehicle kilometres)	10.8	21.8	44.1	66.7	89.8	113.3

Using these figures and the estimated difference in fuel consumption between a conventional diesel bus and a low-carbon hybrid bus, the reduction in fuel consumption and the resultant reduction in fuel costs have been estimated. These figures (for each year between 2005 and 2010) are presented in Table 3.70. The net present value of fuel savings over this time period is presented in Table 3.71.

Table 3.70: Changes in annual fuel consumption and operating costs due to the uptake of low carbon hybrid buses

	2005	2006	2007	2008	2009	2010
Estimated change in annual fuel consumption (milllion litres)	-0.90	-1.82	-3.68	-5.57	-7.50	-9.46
Estimated change in fuel costs (£millions)	-£0.37	-£0.74	-£1.50	-£2.27	-£3.05	-£3.85

Table 3.71: Net Present Value of the change in operating costs due to the uptake of low carbon hybrid buses

	NPV of operating costs (2005-2010)
Estimated change in fuel costs	-£10.08 million

3.7.3 Emissions abatement performance

For low NOx/PM_{10} hybrid buses, it has been assumed that there is an 80% reduction in NOx emissions and 90% reduction in PM_{10} emissions compared to a conventional Euro 3 diesel bus not fitted with a particulate trap. There are no changes in the levels of CO_2 emissions. For low carbon hybrid buses, the reduction in NOx and PM_{10} emissions has been assumed to be 30%, whilst there is also a 30% reduction in CO_2 emissions compared to a conventional diesel bus. The NAEI vehicle emissions factors have been used to provide projections of the effect that increased uptake of low NOx/PM_{10} or low carbon hybrid buses would have on total vehicle emissions between 2005 and 2010. These projections are presented below in Table 3.72 and Table 3.73 for low-NOx/PM_{10} hybrid buses, and in Table 3.74, Table 3.75, and Table 3.76 for low-carbon hybrid buses.

3.7.3.1 Low NOx/PM_{10} hybrid buses

Table 3.72: Estimated reduction in total NOx emissions from road transport due to the increased uptake of low NOx/PM_{10} hybrid buses (2% of the bus fleet by 2010)

NOx emissions (kilotonnes)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total (2005-2010)**
Baseline total NOx emissions from road transport	572.20	534.52	495.15	457.12	417.81	384.37	2861.18
Estimated total NOx emissions with low NOx/PM_{10} hybrids accounting for 10% of bus fleet by 2010	572.15	534.42	494.97	456.87	417.52	384.03	2859.97
Emissions abatement against baseline	**-0.05**	**-0.10**	**-0.18**	**-0.25**	**-0.30**	**-0.34**	**-1.21**
Percentage reduction against baseline	**-0.01%**	**-0.02%**	**-0.04%**	**-0.05%**	**-0.07%**	**-0.09%**	**-0.04%**

Table 3.73: Estimated reduction in total PM_{10} emissions from road transport due to the increased uptake of low NOx/PM_{10} hybrid buses (2% of the bus fleet by 2010)

PM_{10} emissions (kilotonnes)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total (2005-2010)**
Baseline total PM_{10} emissions from road transport	25.59	24.16	22.40	20.70	19.14	17.83	129.82
Estimated total PM_{10} emissions with low NOx/PM_{10} hybrids accounting for 10% of bus fleet by 2010	25.59	24.16	22.40	20.70	19.13	17.82	129.80
Emissions abatement against baseline	**-0.001**	**-0.002**	**-0.003**	**-0.004**	**-0.005**	**-0.005**	**-0.020**
Percentage reduction against baseline	**0.00%**	**-0.01%**	**-0.01%**	**-0.02%**	**-0.02%**	**-0.03%**	**-0.02%**

There is no improvement in fuel consumption for low NOx/PM_{10} hybrid buses and hence no reduction in emissions of CO_2 from these vehicles.

3.7.3.2 Low Carbon hybrid buses

The following tables provide estimates for the impact of low carbon hybrid buses on total UK emissions of NOx, PM_{10}, and CO_2.

Table 3.74: Estimated reduction in total NOx emissions from road transport due to the increased uptake of low CO_2 hybrid buses (2% of the bus fleet by 2010)

NOx emissions (kilotonnes)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total (2005-2010)**
Baseline total NOx emissions from road transport	572.20	534.52	495.15	457.12	417.81	384.37	2861.18
Estimated total NOx emissions with low carbon hybrids accounting for 10% of bus fleet by 2010	572.17	534.47	495.06	457.01	417.70	384.26	2860.67
Emissions abatement against baseline	**-0.03**	**-0.05**	**-0.09**	**-0.11**	**-0.11**	**-0.10**	**-0.50**
Percentage reduction against baseline	**-0.01%**	**-0.01%**	**-0.02%**	**-0.02%**	**-0.03%**	**-0.03%**	**-0.02%**

Table 3.75: Estimated reduction in total PM_{10} emissions from road transport due to the increased uptake of low CO_2 hybrid buses (2% of the bus fleet by 2010)

PM_{10} emissions (kilotonnes)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total (2005-2010)**
Baseline total PM_{10} emissions from road transport	25.59	24.16	22.40	20.70	19.14	17.83	129.82
Estimated total PM_{10} emissions with low carbon hybrids accounting for 10% of bus fleet by 2010	25.59	24.16	22.40	20.70	19.14	17.83	129.81
Emissions abatement against baseline	**-0.001**	**-0.001**	**-0.002**	**-0.001**	**-0.001**	**0.000**	**-0.006**
Percentage reduction against baseline	**0.00%**	**0.00%**	**-0.01%**	**-0.01%**	**0.00%**	**0.00%**	**0.00%**

Table 3.76: Estimated reduction in total CO_2 emissions from road transport due to the increased uptake of low CO_2 hybrid buses (2% of the bus fleet by 2010)

CO_2 emissions (kilotonnes)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total (2005-2010)**
Estimated change in CO_2 emissions due to uptake of hybrid cars (high uptake scenario)	-2.38	-4.81	-9.71	-14.71	-19.79	-24.98	-76.37

3.7.4 Qualitative assessment of wider impacts

Table 3.77 and Table 3.78 provide assessment of the wider impacts of the two hybrid bus scenarios.

Table 3.77: Assessment of wider impacts for low NOx/PM_{10} hybrid buses

Performance criteria	**Qualitative score**
Carbon monoxide emissions	2
Hydrocarbon emissions	2
Ground level ozone	1
Noise	2
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	0
Public/industry acceptability	2
Practicality	-1

Table 3.78: Assessment of wider impacts for Low CO_2 hybrid buses

Performance criteria	Qualitative score
Carbon monoxide emissions	2
Hydrocarbon emissions	2
Ground level ozone	1
Noise	2
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	0
Public/industry acceptability	2
Practicality	-1

3.8 Water Diesel Emulsion fuel for heavy-duty vehicles

3.8.1 Deployment scenarios

Water Diesel Emulsion (WDE) fuels have been specifically developed to help reduce NOx emissions from heavy-duty vehicles. Two scenarios have been proposed for the uptake of Water Diesel Emulsion (WDE) fuels. In the low uptake scenario, it has been assumed that in 2006, 2% of HGVs and 10% of buses run on this fuel, rising to 10% and 50% respectively by 2010. In the high uptake scenario, 10% of HGVs and 100% of buses run on WDE fuels from 2006 onwards.

3.8.2 Implementation costs

3.8.2.1 Capital costs

There are no significant additional capital costs associated with the uptake of WDE fuels. There may be some costs associated with the need for separate fuel storage, but these have not been estimated.

3.8.2.2 Operating costs

It has been assumed that fuel consumption is unaffected by the switch from conventional diesel to WDE, although in practice there may be slight variations in the amount of fuel used. Information from one supplier of WDE fuels has indicated that the retail price of such fuel is typically 3 pence per litre higher than conventional diesel. For the purposes of this analysis, it has therefore been assumed that the retail price of WDE is £0.88 per litre. For bus operators, taking into account the Bus Service Operators Grant, the estimated cost of WDE is £0.43 per litre.

Using NAEI projections for total bus and HGV annual kilometres travelled between 2005 and 2010, it has been possible to estimate the number of kilometres that would be travelled by vehicles running on WDE fuels for the two scenarios, and hence to estimate the additional total fuel costs associated with this fuel. Table 3.79 to Table 3.81 present projected vehicle kilometre data and costs for the low uptake scenario, whilst Table 3.82 to Table 3.84 present the equivalent data for the high uptake scenario.

Table 3.79: Projected vehicle kilometre data associated with increased uptake of WDE fuel (low uptake scenario)

	2005	2006	2007	2008	2009	2010
Rigid trucks - proportion of fleet running on WDE	0.0%	2.0%	4.0%	6.0%	8.0%	10.0%
Rigid trucks - total number of vehicle kilometres travelled by vehicles running on WDE (million vehicle kms)	0.0	328.5	647.8	957.8	1,258.6	1,550.2
Artic trucks - proportion of fleet running on WDE	0.0%	2.0%	4.0%	6.0%	8.0%	10.0%
Artic trucks - total number of vehicle kilometres travelled by vehicles running on WDE (million vehicle kms)	0.0	312.2	628.9	950.1	1,275.7	1,605.8
Buses - proportion of fleet running on WDE	0.0%	10.0%	20.0%	30.0%	40.0%	50.0%
Buses - total number of vehicle kilometres travelled by vehicles running on WDE (million vehicle kms)	0.0	545.4	1,101.5	1,668.1	2,245.4	2,833.2

Table 3.80: WDE fuel (low uptake scenario): annual additional operating costs (2005-2010)

	2005	2006	2007	2008	2009	2010
Rigid trucks	£0.00	£3.39	£6.69	£9.90	£13.01	£16.02
Artic trucks	£0.00	£3.57	£7.20	£10.88	£14.60	£18.38
Buses	£0.00	£4.55	£9.20	£13.93	£18.75	£23.66
TOTAL	**£0.00**	**£11.52**	**£23.09**	**£34.70**	**£46.36**	**£58.06**

Table 3.81: Net Present Value of operating costs between 2005 and 2010 for increased uptake of WDE fuel (low uptake scenario)

	NPV of operating costs (2005-2010)
Total fuel savings	£148.08 million

Table 3.82: Projected vehicle kilometre data associated with increased uptake of WDE fuel (high uptake scenario)

	2005	2006	2007	2008	2009	2010
Rigid trucks - proportion of fleet running on WDE	0.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Rigid trucks - total number of vehicle kilometres travelled by vehicles running on WDE (million vehicle kms)	0.0	1,642.5	1,619.4	1,596.3	1,573.3	1,550.2
Artic trucks - proportion of fleet running on WDE	0.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Artic trucks - total number of vehicle kilometres travelled by vehicles running on WDE (million vehicle kms)	0.0	1,561.1	1,572.3	1,583.5	1,594.6	1,605.8
Buses - proportion of fleet running on WDE	0.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Buses - total number of vehicle kilometres travelled by vehicles running on WDE (million vehicle kms)	0.0	5,454.4	5,507.3	5,560.4	5,613.4	5,666.4

Table 3.83: WDE fuel (high uptake scenario): annual additional operating costs (2005-2010)

	2005	2006	2007	2008	2009	2010
Rigid trucks	£0.00	£16.97	£16.73	£16.49	£16.26	£16.02
Artic trucks	£0.00	£17.87	£18.00	£18.13	£18.25	£18.38
Buses	£0.00	£45.54	£45.98	£46.43	£46.87	£47.31
TOTAL	**£0.00**	**£80.38**	**£80.72**	**£81.05**	**£81.38**	**£81.71**

Table 3.84: Net Present Value of operating costs between 2005 and 2010 for increased uptake of WDE fuel (high uptake scenario)

	NPV of operating costs (2005-2010)
Total fuel savings	£353.46 million

3.8.3 Emissions abatement performance

The reduction in vehicle emissions due to the introduction of Water Diesel Emulsion fuel has been based on a 13% reduction in NOx emissions, a 25% reduction in PM_{10} emissions for those vehicles not fitted with particulate traps, and no reduction in CO_2 emissions. The impacts on total vehicle emissions for the two deployment scenarios are presented in Table 3.85 to Table 3.88.

3.8.3.1 Low uptake scenario

Table 3.85: Estimated reduction in total NOx emissions from road transport due to the uptake of WDE fuel (10% of HGVs and 50% of buses by 2010)

NOx emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total NOx emissions from road transport	572.20	534.52	495.15	457.12	417.81	384.37	2861.18
Estimated total NOx emissions with increased uptake of WDE fuel (low uptake scenario)	572.20	533.31	492.89	454.01	414.24	380.58	2847.23
Emissions abatement against baseline	**0.00**	**-1.20**	**-2.26**	**-3.11**	**-3.57**	**-3.79**	**-13.94**
Percentage reduction against baseline	**0.00%**	**-0.23%**	**-0.46%**	**-0.68%**	**-0.86%**	**-0.99%**	**-0.49%**

Table 3.86: Estimated reduction in total PM_{10} emissions from road transport due to the uptake of WDE fuel (10% of HGVs and 50% of buses by 2010)

PM_{10} emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total PM_{10} emissions from road transport	25.59	24.16	22.40	20.70	19.14	17.83	129.82
Estimated total PM_{10} emissions with increased uptake of WDE fuel (low uptake scenario)	25.59	24.11	22.28	20.56	18.99	17.68	129.20
Emissions abatement against baseline	**0.00**	**-0.05**	**-0.12**	**-0.15**	**-0.15**	**-0.15**	**-0.62**
Percentage reduction against baseline	**0.00%**	**-0.21%**	**-0.54%**	**-0.70%**	**-0.80%**	**-0.84%**	**-0.48%**

3.8.3.2 High uptake scenario

Table 3.87: Estimated reduction in total NOx emissions from road transport due to the uptake of WDE fuel (10% of HGVs and 100% of buses from 2006 onwards)

NOx emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total NOx emissions from road transport	572.20	534.52	495.15	457.12	417.81	384.37	2861.18
Estimated total NOx emissions with increased uptake of WDE fuel (high uptake scenario)	572.20	525.83	486.99	449.59	411.26	378.72	2824.60
Emissions abatement against baseline	**0.00**	**-8.68**	**-8.16**	**-7.53**	**-6.56**	**-5.65**	**-36.58**
Percentage reduction against baseline	**0.00%**	**-1.62%**	**-1.65%**	**-1.65%**	**-1.57%**	**-1.47%**	**-1.28%**

Table 3.88: Estimated reduction in total PM_{10} emissions from road transport due to the uptake of WDE fuel (10% of HGVs and 100% of buses from 2006 onwards)

PM_{10} emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total PM_{10} emissions from road transport	25.59	24.16	22.40	20.70	19.14	17.83	129.82
Estimated total PM_{10} emissions with increased uptake of WDE fuel (high uptake scenario)	25.59	23.77	22.09	20.46	18.95	17.68	128.53
Emissions abatement against baseline	**0.00**	**-0.39**	**-0.31**	**-0.25**	**-0.19**	**-0.15**	**-1.29**
Percentage reduction against baseline	**0.00%**	**-1.62%**	**-1.40%**	**-1.19%**	**-1.00%**	**-0.83%**	**-1.00%**

3.8.4 Qualitative assessment of wider impacts

Assessments of the wider impacts of the two scenarios for the uptake of WDE fuels are presented in Table 3.89 and Table 3.90.

Table 3.89: Assessment of wider impacts for the increased uptake of WDE fuel (low uptake scenario)

Performance criteria	Qualitative score
Carbon monoxide emissions	0
Hydrocarbon emissions	0
Ground level ozone	1
Noise	0
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	0
Public/industry acceptability	0
Practicality	0

Table 3.90: Assessment of wider impacts for the increased uptake of WDE fuel (high uptake scenario)

Performance criteria	Qualitative score
Carbon monoxide emissions	0
Hydrocarbon emissions	0
Ground level ozone	2
Noise	0
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	0
Public/industry acceptability	0
Practicality	-1

3.9 Scrappage scheme for pre-Euro and Euro 1 passenger cars

3.9.1 Deployment scenario

The scenarios developed for this option assume that a financial incentive is in place that encourages owners of pre-Euro and Euro 1 passenger cars to scrap their vehicles earlier than would otherwise have happened. It has been assumed that such a scheme would lead to a 10% increase in the numbers of such vehicles scrapped over and above the annual average scrappage rate.

As it is not possible to know how many vehicles will leave the vehicle parc between 2005 and 2010, historical data on the numbers of older vehicles leaving the vehicle parc between 1993 and 2003[12] has been used to provide estimates of the likely numbers of pre-Euro and Euro 1 vehicles that will be scrapped without the presence of a scrappage incentive scheme. It should be noted that pre-Euro cars are assumed to include all passenger cars registered before 1993, whilst Euro 1 cars are those that were registered between 1993 and 1996. Table 3.91 provides estimates for the numbers of pre-Euro and Euro 1 passenger cars scrapped in each year between 2005 and 2010 without and with a scrappage incentive scheme in place.

Table 3.91: Projected numbers of pre-Euro and Euro 1 passenger cars scrapped between 2005 and 2010 with and without a scrappage incentive scheme

	2005	2006	2007	2008	2009	2010
Estimated number of pre-Euro and Euro 1 cars scrapped without incentive scheme	1,370,400	1,149,200	862,000	571,700	355,800	220,800
Estimated number of pre-Euro and Euro 1 cars scrapped with scrappage scheme in place	1,507,440	1,264,120	948,200	628,870	391,380	242,880

3.9.2 Implementation costs

3.9.2.1 Capital costs

It has been assumed that there are no additional capital costs associated with this option.

3.9.2.2 Operating costs

The costs associated with this option are based on the level of financial incentives available to owners of eligible vehicles. It has been assumed that the typical costs associated with such a scheme range from £250 to £500 per vehicle, inclusive of administrative costs. It should be noted that although such a scheme may increase the number of gross polluting vehicles that are scrapped, the owners of all scrapped pre-Euro and Euro 1 passenger cars, including those that would have been scrapped anyway without the existence of an incentive scheme would be eligible for the incentives. The costs presented below are based on the assumption that the owners of all pre-Euro and Euro 1 cars that are scrapped in each year receive a financial incentive.

Table 3.92: Estimated annual operating costs associated with a scrappage incentive scheme for pre-Euro and Euro 1 passenger cars

	2005	2006	2007	2008	2009	2010
Low cost option (costs in £millions)	£376.86	£316.03	£237.05	£157.22	£97.85	£60.72
High cost option (costs in £millions)	£753.72	£632.06	£474.10	£314.44	£195.69	£121.44

Table 3.93: Net Present Value of operating costs between 2005 and 2010 associated with a scrappage incentive scheme for pre-Euro and Euro 1 passenger cars

	NPV of operating costs (2005-2010)
Total costs (low cost option)	£1,141.72 million
Total costs (high cost option)	£2,283.45 million

3.9.3 Emissions abatement performance

The effect of a scrappage incentive scheme on total UK road transport emissions of NOx and PM_{10} has been modelled in detail. The results of this emissions modelling are presented in Table 3.94 and Table 3.95 below. It has been assumed that a scrappage incentive scheme would not lead to reductions in CO_2 emissions.

Table 3.94: Estimated reduction in total NOx emissions from road transport due to scrappage incentive scheme for pre-Euro and Euro 1 passenger cars

NOx emissions (kilotonnes)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total (2005-2010)**
Baseline total NOx emissions from road transport	572.20	534.52	495.15	457.12	417.81	384.37	2861.18
Estimated total NOx emissions with scrappage scheme in place	572.20	511.67	475.83	441.57	406.51	376.73	2784.51
Emissions abatement against baseline	**0.00**	**-22.85**	**-19.33**	**-15.55**	**-11.30**	**-7.64**	**-76.67**
Percentage reduction against baseline	**0.00%**	**-4.27%**	**-3.90%**	**-3.40%**	**-2.70%**	**-1.99%**	**-2.68%**

Table 3.95: Estimated reduction in total PM_{10} emissions from road transport due to scrappage incentive scheme for pre-Euro and Euro 1 passenger cars

PM_{10} emissions (kilotonnes)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total (2005-2010)**
Baseline total PM_{10} emissions from road transport	25.59	24.16	22.40	20.70	19.14	17.83	129.82
Estimated total PM_{10} emissions with scrappage scheme in place	25.59	23.59	21.85	20.21	18.75	17.53	127.52
Emissions abatement against baseline	**0.00**	**-0.57**	**-0.55**	**-0.49**	**-0.39**	**-0.30**	**-2.31**
Percentage reduction against baseline	**0.00%**	**-2.36%**	**-2.47%**	**-2.37%**	**-2.05%**	**-1.68%**	**-1.78%**

3.9.4 Qualitative assessment of wider impacts

An assessment of the wider impacts of implementing a scrappage incentive scheme is presented in Table 3.96.

Table 3.96: Assessment of the wider impacts of a scrappage scheme for pre-Euro and Euro 1 passenger cars

Performance criteria	Qualitative score
Carbon monoxide emissions	1
Hydrocarbon emissions	1
Ground level ozone	1
Noise	0
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	-1
Public/industry acceptability	1
Practicality	-2

3.10 Low Emission Zones

3.10.1 Deployment scenario

Using data from the London Low Emission Zone Feasibility Study[6], and from a study conducted on the potential emissions benefits of applying a Low Emission Zone to a large metropolitan area[7], estimates have been made for the costs and benefits associated with introducing LEZs to London and the next eight largest urban areas. It has been assumed that these LEZs would only apply to heavy-duty vehicles (trucks and buses), and would impose a minimum emissions standard of Euro 2 with Reduced Pollution Certificate (RPC); the RPC requirement means that a particulate trap would need to be fitted[e]. It has been assumed that these LEZ schemes would come into force in 2007.

3.10.2 Implementation costs

The costs associated with implementing LEZs consist of set up costs (upgrading vehicles, providing a means of enforcing the scheme such as a fixed camera monitoring network), and operating costs (e.g. personnel to monitor and enforce the scheme, etc). Estimates for the set-up and operating costs associated with a London LEZ were obtained from the London LEZ Feasibility study. There are currently no available data on the likely costs of implementing LEZ for other urban areas, and hence the London scheme figures were scaled down in order to provide an initial estimate of the costs in the next eight largest metropolitan areas; for each of these areas, the costs were assumed to be 30% of those in London.

3.10.2.1 Capital costs

Capital costs have been separated into scheme set-up costs and vehicle upgrade costs. As described above, the set up costs include the costs of setting up camera enforcement networks similar to those used for the London Congestion Charging scheme. Other methods of enforcement may become available, but in the near future, this model is likely to be the most cost-effective method. Annualised set-up costs have been obtained by discounting the set-up

[e] In January 1999, the Government introduced tax incentives to help reduce particulate emissions from heavy duty vehicles. Commercial operators who are able to demonstrate that their buses or trucks have been modified or re-engineered to meet stricter limits for particulate emissions than applied at the time of vehicle's manufacture are eligible for a Reduced Pollution Certificate which enables them to claim a reduction in the rate of Vehicle Excise Duty payable. Modifications include the fitment of diesel particulate filters, or re-engining the vehicle with an engine that emits reduced levels of particulates. The specific eligibility requirements for obtaining a Reduced Pollution Certificate are detailed in Schedule 2 of The Road Vehicles (Registration and Licensing) Regulations 2002 (SI 2002 no 2742).

costs over an eight-year lifetime. A relatively short life time has been applied to the set-up costs, as unless the minimum emissions standards are updated, LEZ schemes tend to become obsolete after a few years as the emissions performance of the vehicle fleet improves due to older, more polluting vehicles naturally disappearing from the vehicle parc as they reach the end of their lives.

Vehicle upgrade costs consist of the costs of replacing, re-engining, or retrofitting vehicles that do not meet the minimum emissions standards. The average cost of all vehicle upgrade activities has been discounted over a time period of seven years.

Table 3.97: Estimated total and annualised costs of setting up Low Emission Zone schemes in London and the next eight largest urban areas in the UK

		Total cost (£millions)	Annualised cost (£millions)
Set up costs	Low estimate	£20.40	£2.45
	High estimate	£36.04	£4.33
Upgrading vehicles	Low estimate	£217.60	£26.16
	High estimate	£459.00	£55.19

Table 3.98: Net Present Value of set-up and vehicle upgrade costs between 2005 and 2010 associated with Low Emission Zone schemes

	NPV of set-up and upgrade costs (2005-2010)
Low estimate	£114.47 million
High estimate	£238.10 million

3.10.3 Operating costs and revenues

Estimates of the annual operating costs and revenues have again been derived from the London Low Emission Zone Feasibility Study. Operating costs include the costs of operating and maintaining the camera network, as well as staff costs associated with enforcement activities. Revenues associated with LEZ schemes are due to financial penalties imposed on vehicle operators that do not comply with a LEZ.

Table 3.99: Estimated annual operating costs and revenues associated with Low Emissions Zone schemes in London and the eight next largest urban areas

		Annual costs/ revenues (£millions)
Operating costs	Low estimate	£12.00
	High estimate	£16.80
Revenues	Low estimate	-£2.40
	High estimate	-£9.60

Table 3.100: Net Present Value of operating costs between 2005 and 2010 associated with Low Emission Zone schemes

	NPV of operating costs and revenues (2005-2010)
Low estimate	£49.95 million
High estimate	£37.47 million

3.10.4 Emissions abatement performance

Estimates of the emissions abatement performance of Low Emission Zones have been based on the London LEZ Feasibility Study[6], and on emissions modelling work previously carried out that examined the potential impact of implementing an LEZ in Sheffield[7]. The results from the London LEZ feasibility study have been directly used to provide estimates of the likely effects on NOx and PM_{10} emissions in London, whilst the results from the Sheffield modelling study have been used as a proxy for all seven of the next largest urban areas in the UK. It must be stressed that this is a big assumption to make; in practice the impact of LEZ schemes will be different in each urban area due to differences in local traffic parameters.

It has also been necessary to take into account that if an LEZ is implemented in an urban area, it only has a limited timespan over which it has a useful effect in reducing vehicle emissions. Increasingly stringent emissions standards mean that the emissions performance of the vehicle fleet is continuously improving over time as newer and cleaner vehicles replace older, more polluting vehicles that have reached the end of their lives. Implementing an LEZ effectively speeds this process up by removing the gross polluters earlier than would otherwise happen. However, there comes a point in time where the LEZ fails to have any more effect on reducing emissions over what would have happened without the LEZ in place. Research carried out for the London LEZ Feasibility Study[6] identified that for a LEZ scheme implemented in London in 2007 and based on a minimum standard of Euro 2 + RPC, the emissions abatement performance of the scheme compared to the baseline scenario would drop to zero by 2015. The diminishing performance of LEZ over time has been taken into account in the emissions analysis undertaken for this study.

Table 3.101: Estimated reduction in total NOx emissions from road transport due to the implementation of Low Emission Zones

NOx emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total NOx emissions from road transport	572.20	534.52	495.15	457.12	417.81	384.37	2861.18
Estimated total NOx emissions with LEZ schemes in place	572.20	534.52	491.29	453.99	415.37	382.50	2849.88
Emissions abatement against baseline	**0.00**	**0.00**	**-3.86**	**-3.12**	**-2.45**	**-1.87**	**-11.30**
Percentage reduction against baseline	**0.00%**	**0.00%**	**-0.78%**	**-0.68%**	**-0.59%**	**-0.49%**	**-0.39%**

Table 3.102: Estimated reduction in total PM_{10} emissions from road transport due to the implementation of Low Emission Zones

PM_{10} emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total PM_{10} emissions from road transport	25.59	24.16	22.40	20.70	19.14	17.83	129.82
Estimated total PM_{10} emissions with LEZ schemes in place	25.59	24.16	21.84	20.27	18.81	17.58	128.25
Emissions abatement against baseline	**0.00**	**0.00**	**-0.56**	**-0.43**	**-0.33**	**-0.25**	**-1.57**
Percentage reduction against baseline	**0.00%**	**0.00%**	**-2.50%**	**-2.09%**	**-1.72%**	**-1.39%**	**-1.21%**

It must be noted that the implementation of Low Emission Zones would be likely to have an impact on primary NO_2 emissions. If the minimum standard for LEZs is set at Euro 2 + RPC, then a significant number of heavy duty vehicles would need to be retrofitted with DPFs, and in the UK, Continuously Regenerating Traps (CRTs) are the most commonly used type of DPF. As discussed in Section 2.4, CRTs lead to increased levels of primary NO_2 emissions from vehicles fitted with this technology, and consequently the introduction of Low Emission Zones may have a detrimental effect on NO_2 concentrations in urban areas. This would be of particular concern in London where NO_2 concentration limit values for 2010 are currently unlikely to be met. Further analysis will be required to understand in detail the impacts of introducing LEZs to the major urban areas of the UK.

3.10.5 Qualitative assessment of wider impacts

Table 3.103 provides an assessment of the wider impacts of introducing Low Emission Zone schemes to the largest urban areas in the UK.

Table 3.103: Assessment of the wider impacts of LEZ schemes for London and the next eight largest urban areas

Performance criteria	Qualitative score
Carbon monoxide emissions	1
Hydrocarbon emissions	1
Ground level ozone	1
Noise	0
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	-2
Public/industry acceptability	-1
Practicality	-1

3.11 Access control measures to restrict private car use in urban centres

3.11.1 Deployment scenario

Access control measures consist of options that restrict certain types of traffic from particular areas. LEZ schemes can be considered as a type of access control measure, but for this scenario, the restriction that has been examined entails removing all passenger cars from specific areas of city centres. The type of scheme that has been examined is modelled on elements of the Oxford Transport Strategy, where there are daytime restrictions on the transit of private cars through the city centre. The main aim of this scheme is to reduce traffic congestion rather than improve vehicle emissions, although there are side benefits of this nature associated with such schemes.

For this measure, it has been assumed that similar access control schemes have been implemented in the eight largest urban areas outside of London. The emissions benefits are based on work that was carried out to model the effect of such a scheme on Sheffield[7]; in the lack of any other hard data at this point, the emissions benefits have been assumed to be the same in the other seven urban areas. The costs associated with the scheme are based on the actual costs of implementing the city centre car restrictions in Oxford.

3.11.2 Implementation costs

3.11.2.1 Capital costs

Table 3.104 below presents data obtained from Oxfordshire County Council on the estimated costs of setting up the restrictions on private car traffic in the city centre. These costs include changes to road layouts, the pedestrianisation of roads, and new road signs. The costs have been adjusted to 2004 prices and have been annualised using a life time of 25 years.

Table 3.104: Total and annualised costs associated with the Oxford Transport Strategy's private car access control measures

	Total cost (£millions)	Annualised cost (£millions)
Set up costs	£4.80	£0.29

It has been assumed that the costs of implementing similar schemes in the eight largest urban areas would be the same as for the Oxford scheme. The total estimated set-up costs for all of these schemes are presented in Table 3.105 below, and the net present value of set-up costs between 2005 and 2010 of the schemes is presented in Table 3.106. It should be noted that in practice, the scheme costs in the largest UK urban areas will be different to the costs of implementing the Oxford scheme. However, in the lack of any other hard data, these figures have been used.

Table 3.105: Estimated total and annualised costs associated with setting up access control schemes in the largest urban areas in the UK (excluding London)

	Total cost (£millions)	Annualised cost (£millions)
Set up costs	£38.40	£2.33

Table 3.106: Net Present Value of set-up costs between 2005 and 2010 for access control schemes

	NPV of set-up costs (2005-2010)
Access control schemes	£12.41 million

3.11.2.2 Operating costs

No information is available on the typical operating costs associated with such schemes, although such costs will typically consist of enforcement activities.

3.11.3 Emissions abatement performance

The estimates of the emissions abatement performance of access control measures for restricting private car use are based on modelling work previously carried out to examine the potential emissions benefits of such a scheme, as applied to Sheffield city centre. The results from this emissions modelling exercise have been used as a proxy for what would happen in a typical large urban area, and have been factored up to provide estimates of the effects of introducing similar schemes in all eight of the largest metropolitan areas outside of London.

The original modelling exercise only assessed the potential emissions benefits for 2005. To estimate the effect of the option in future years, it was necessary to examine how total baseline emissions from passenger cars are projected to decrease between 2005 and 2010, and then factor the estimated 2005 emissions abatement performance of this measure downwards for each year between 2006 and 2010 proportionately.

Table 3.107 and Table 3.108 respectively show how baseline UK passenger car NOx and PM_{10} emissions are projected to change over the period between 2005 and 2010[f].

Table 3.107: Projected baseline NOx emissions from passenger cars

NOx emissions (kilotonnes)	2005	2006	2007	2008	2009	2010
Baseline total NOx emissions from passenger cars	219.53	199.42	182.20	167.21	155.41	146.26
Total passenger car NOx emissions as a percentage of 2005 passenger car NOx emissions	100%	91%	83%	76%	71%	67%

Table 3.108: Projected baseline PM_{10} emissions from passenger cars

PM_{10} emissions (kilotonnes)	2005	2006	2007	2008	2009	2010
Baseline total NOx emissions from passenger cars	6.71	6.38	6.07	5.78	5.59	5.46
Total passenger car NOx emissions as a percentage of 2005 passenger car NOx emissions	100%	95%	91%	86%	83%	81%

[f] Baseline passenger car emissions projections for future years modelled by Netcen

Using the percentage figures calculated above in Table 3.107 and Table 3.108, the NOx and PM_{10} emissions abatement performance of access control measures for private cars in the eight largest metropolitan areas has been estimated for each of the years from 2005 to 2010. These estimates are presented below in Table 3.109 and Table 3.110.

Table 3.109: Estimated reduction in total NOx emissions from road transport due to the implementation of access control schemes restricting private car use

NOx emissions (kilotonnes)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total (2005-2010)**
Baseline total NOx emissions from road transport	572.20	534.52	495.15	457.12	417.81	384.37	2861.18
Estimated total NOx emissions with access control schemes in place	572.12	534.45	495.09	457.06	417.76	384.32	2860.79
Emissions abatement against baseline	**-0.08**	**-0.07**	**-0.07**	**-0.06**	**-0.06**	**-0.05**	**-0.39**
Percentage reduction against baseline	**-0.01%**	**-0.01%**	**-0.01%**	**-0.01%**	**-0.01%**	**-0.01%**	**-0.01%**

Table 3.110: Estimated reduction in total PM_{10} emissions from road transport due to the implementation of access control schemes restricting private car use

PM_{10} emissions (kilotonnes)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total (2005-2010)**
Baseline total PM_{10} emissions from road transport	25.59	24.16	22.40	20.70	19.14	17.83	129.82
Estimated total PM_{10} emissions with access control schemes in place	25.58	24.16	22.40	20.70	19.13	17.82	129.79
Emissions abatement against baseline	**-0.01**	**-0.01**	**-0.01**	**0.00**	**0.00**	**0.00**	**-0.03**
Percentage reduction against baseline	**-0.02%**	**-0.02%**	**-0.02%**	**-0.02%**	**-0.02%**	**-0.03%**	**-0.02%**

3.11.4 Qualitative assessment of wider impacts

Table 3.111: Assessment of the wider impacts of access control schemes for restricting private cars in urban centres

Performance criteria	Qualitative score
Carbon monoxide emissions	1
Hydrocarbon emissions	1
Ground level ozone	1
Noise	1
Congestion	3
Accident rate	2
Social cohesion	-1
Quality of life	2
Distribution effects	0
Public/industry acceptability	-2
Practicality	-2

3.12 Lorry road user charging scheme

3.12.1 Deployment scenario

The Lorry Road User Charging scheme is planned as a system by which all heavy goods vehicles travelling on UK roads would be subject to a distance-based charge. The idea is that the scheme would be revenue neutral for UK haulage operators, as the charges would be offset against fuel duty reductions/rebates. For non-UK registered trucks operating in the UK, however, the scheme will for the first time impose charges on foreign hauliers for the use of the UK road network. It is currently anticipated that the scheme will lead to a 0.3% reduction in the total number of vehicle kilometres travelled by all HGVs in the UK[g].

3.12.2 Implementation costs

3.12.2.1 Capital costs

The capital costs associated with the scheme consist of the costs of purchasing and fitting on-board electronic monitoring units that are able to provide information on distance travelled by an individual vehicle, as well as its location. The unit costs of this equipment have been assumed to be the same as the costs of the on-board monitoring equipment that could be used in the proposed National Road Pricing Scheme[13] (see Section 4.6). The estimated unit costs are presented below in Table 3.112. The total costs associated with equipping the HGV fleet with on-board equipment is based on fitting this equipment to the 426,000 UK registered trucks already in operation, as well as to new trucks entering the vehicle parc each year. The estimated annualised costs of fitting all of these vehicles with this equipment are presented in Table 3.113 (based on annualising the costs over a seven year lifetime). The Net Present Value of capital costs over the period 2005 to 2010 is presented in Table 3.114.

[g] Estimated effect of Lorry Road User Charging scheme provided by Department for Transport to AEA Technology's Netcen operating division to carry out emissions modelling work.

Table 3.112: Estimated unit costs of on-board monitoring equipment

	Unit cost	Annualised cost
On-board monitoring equipment (low estimate)	£100	£16.35
On-board monitoring equipment (high estimate)	£525	£85.86

Table 3.113: Annualised capital costs associated with equipping existing and new vehicles with on-board monitoring units

	2005	2006	2007	2008	2009	2010
On-board monitoring equipment (low cost estimate) (£millions)	£0.00	£0.00	£7.00	£7.71	£8.41	£9.11
On-board monitoring equipment (high cost estimate) (£millions)	£0.00	£0.00	£36.73	£40.46	£44.16	£47.83

Table 3.114: Net Present Value of capital costs between 2005 and 2010

	NPV of capital costs (2005-2010)
Low cost estimate	£32.23 million
High cost estimate	£169.19 million

3.12.2.2 Operating costs

The annual costs of operating the Lorry Road User Charging scheme have been estimated to be approximately £700 million per year[14]. Based on this figure, the net present value of operating costs between 2005 and 2010 (assuming that the scheme comes into operation in 2007/8) have been calculated and are presented below.

Table 3.115: Net Present Value of operating costs between 2005 and 2010

	NPV of operating costs (2005-2010)
Lorry charging scheme	£2,571.16 million

3.12.3 Emissions abatement performance

The emissions abatement performance of the scheme has been modelled using the NAEI baseline projections for total UK emissions of NOx and PM_{10}, and factoring the annual number of HGV kilometres travelled downwards by 0.3%. The results of this modelling are presented below in Table 3.116 and Table 3.117. No estimates are available for changes in CO_2 emissions.

Table 3.116: Estimated reduction in total NOx emissions from road transport due to the implementation of the lorry road user charging scheme

NOx emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total NOx emissions from road transport	572.20	534.52	495.15	457.12	417.81	384.37	2861.18
Estimated total NOx emissions with lorry charging scheme in place	572.20	534.41	494.95	456.84	417.49	384.01	2859.91
Emissions abatement against baseline	**0.00**	**-0.11**	**-0.20**	**-0.27**	**-0.32**	**-0.36**	**-1.26**
Percentage reduction against baseline	**0.00%**	**-0.02%**	**-0.04%**	**-0.06%**	**-0.08%**	**-0.09%**	**-0.04%**

Table 3.117: Estimated reduction in total PM_{10} emissions from road transport due to the implementation of access control schemes restricting private car use

PM_{10} emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total PM_{10} emissions from road transport	25.59	24.16	22.40	20.70	19.14	17.83	129.82
Estimated total PM_{10} emissions with lorry charging scheme in place	25.59	24.16	22.40	20.70	19.13	17.82	129.79
Emissions abatement against baseline	**0.00**	**0.00**	**0.00**	**-0.01**	**-0.01**	**-0.01**	**-0.03**
Percentage reduction against baseline	**0.00%**	**-0.01%**	**-0.02%**	**-0.03%**	**-0.03%**	**-0.04%**	**-0.02%**

3.12.4 Qualitative assessment of wider impacts

Table 3.118: Assessment of the wider impacts of the Lorry Road User Charging Scheme

Performance criteria	Qualitative score
Carbon monoxide emissions	1
Hydrocarbon emissions	1
Ground level ozone	1
Noise	0
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	0
Distribution effects	0
Public/industry acceptability	1
Practicality	-1

3.13 Public transport priority measures

3.13.1 Deployment scenario

This option covers public transport traffic priority measures such as bus lanes and guided busways, which have so far primarily been used to alleviate congestion in urban centres. The deployment scenario estimates the costs and benefits of introducing additional schemes of this nature into the eight largest urban areas outside of London. Estimated impacts of such schemes are based on two schemes that have already been implemented in West Yorkshire.

3.13.2 Implementation costs

3.13.2.1 Capital costs

The estimated capital costs of implementing bus priority schemes in the largest urban areas have been based on the costs of the South Bradford and East Leeds Quality Bus Initiatives. The total and annualised costs of these two schemes are presented below in Table 3.119. The scheme costs have been annualised over a lifetime of 30 years.

Table 3.119: Total and annualised costs of implementing a bus priority scheme

	Total cost	Annualised cost
Unit capital costs (low estimate) (£millions)	£11.40	£0.62
Unit capital costs (high estimate) (£millions)	£17.30	£0.94

It has been assumed that the cost of implementing similar bus priority schemes in other urban areas is the same as the costs incurred in Leeds and South Bradford for the two Quality Bus Initiatives. It should be stressed that in practice, scheme costs will vary according to location and specific scheme layout, but in the absence of other hard cost data, the costs have been assumed to be the same. The total estimated costs and the annualised costs of implementing similar schemes in the eight urban areas are presented below in Table 3.120.

Table 3.120: Total and annualised costs of implementing bus priority schemes in eight large urban areas.

	Total cost	Annualised cost
Capital costs for schemes in 8 urban areas (low estimate) (£millions)	£91.20	£4.96
Capital costs for schemes in 8 urban areas (high estimate) (£millions)	£13.84	£7.52

Using the data presented above, estimates for the Net Present Value of capital costs over the period 2005-2010 have been calculated. These figures are presented in Table 3.121.

Table 3.121: Net Present Value of capital costs between 2005 and 2010

	NPV of capital costs (2005-2010)
Bus priority schemes in 8 urban areas (low cost estimate)	£29.75 million
Bus priority schemes in 8 urban areas (high cost estimate)	£45.15 million

3.13.3 Emissions abatement performance

The emissions abatement performance of bus priority schemes has been estimated using the results of previous emissions modelling on the impacts of introducing bus priority schemes in Sheffield. It has been assumed that the abatement performance modelled for Sheffield would be replicated in the other urban areas. In reality, the emissions abatement performance in each urban area would be strongly dependent on local conditions – in particular traffic flows, traffic composition, road layouts and geography, etc, but it is beyond the scope of this study to carry out detailed modelling of individual urban areas. Any further work on this option would need to examine these issues in detail.

The estimated emissions abatement performance associated with implementing bus priority schemes in the eight urban areas is presented in the following sets of Tables. Table 3.122 and Table 3.123 present the lower estimates for the abatement of NOx and PM_{10} emissions, whilst Table 3.124 and Table 3.125 present the upper estimates for the reduction in pollutant emissions.

Table 3.122: Estimated reduction in total NOx emissions from road transport due to the implementation of the bus priority schemes (lower estimate of emissions abatement performance)

NOx emissions (kilotonnes)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total (2005-2010)**
Baseline total NOx emissions from road transport	572.20	534.52	495.15	457.12	417.81	384.37	2861.18
Estimated total NOx emissions with additional bus priority schemes in place	572.20	534.52	495.15	457.12	417.81	384.37	2861.16
Emissions abatement against baseline	**-0.003**	**-0.003**	**-0.002**	**-0.002**	**-0.002**	**-0.002**	**-0.014**
Percentage reduction against baseline	**-0.001%**	**-0.001%**	**-0.001%**	**-0.001%**	**-0.001%**	**-0.001%**	**-0.001%**

Table 3.123: Estimated reduction in total PM_{10} emissions from road transport due to the implementation of the bus priority schemes (lower estimate of emissions abatement performance)

PM_{10} emissions (kilotonnes)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total (2005-2010)**
Baseline total PM_{10} emissions from road transport	25.59	24.16	22.40	20.70	19.14	17.83	129.82
Estimated total PM_{10} emissions with additional bus priority schemes in place	25.59	24.16	22.40	20.70	19.14	17.83	129.82
Emissions abatement against baseline	**-0.001**	**-0.001**	**-0.001**	**-0.001**	**-0.001**	**-0.001**	**-0.004**
Percentage reduction against baseline	**-0.003%**	**-0.003%**	**-0.003%**	**-0.003%**	**-0.003%**	**-0.003%**	**-0.003%**

Table 3.124: Estimated reduction in total NOx emissions from road transport due to the implementation of the bus priority schemes (upper estimate of emissions abatement performance)

NOx emissions (kilotonnes)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total (2005-2010)**
Baseline total NOx emissions from road transport	572.20	534.52	495.15	457.12	417.81	384.37	2861.18
Estimated total NOx emissions with additional bus priority schemes in place	572.16	534.48	495.12	457.08	417.78	384.34	2860.97
Emissions abatement against baseline	**-0.04**	**-0.04**	**-0.04**	**-0.03**	**-0.03**	**-0.03**	**-0.21**
Percentage reduction against baseline	**-0.01%**	**-0.01%**	**-0.01%**	**-0.01%**	**-0.01%**	**-0.01%**	**-0.01%**

Table 3.125: Estimated reduction in total PM_{10} emissions from road transport due to the implementation of the bus priority schemes (upper estimate of emissions abatement performance)

PM_{10} emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total PM_{10} emissions from road transport	25.59	24.16	22.40	20.70	19.14	17.83	129.82
Estimated total PM_{10} emissions with additional bus priority schemes in place	25.58	24.15	22.39	20.70	19.13	17.82	129.77
Emissions abatement against baseline	**-0.01**	**-0.01**	**-0.01**	**-0.01**	**-0.01**	**-0.01**	**-0.05**
Percentage reduction against baseline	**-0.04%**	**-0.04%**	**-0.04%**	**-0.04%**	**-0.04%**	**-0.04%**	**-0.04%**

3.13.4 Qualitative assessment of wider impacts

Table 3.126: Assessment of the wider impacts of public transport priority measures

Performance criteria	Qualitative score
Carbon monoxide emissions	1
Hydrocarbon emissions	1
Ground level ozone	1
Noise	0
Congestion	1
Accident rate	0
Social cohesion	1
Quality of life	2
Distribution effects	2
Public/industry acceptability	0
Practicality	-1

3.14 Speed policy review for motorways

3.14.1 Deployment scenario

Vehicle emissions on high speed roads close to urban areas can be reduced by forcing traffic to travel at slower speeds. One method to achieve this would be based on implementing speed restrictions on specific sections of motorways that pass close to urban centres, limiting traffic to a maximum speed of 50 miles per hour. This option has been examined on the basis that such a measure would be implemented on stretches of high speed road that are in close proximity to the eight largest urban centres in the UK. The costs and emissions benefits associated with this measure are based on previous research undertaken to estimate the costs and benefits associated with implementing this option on a stretch of the M1 close to Sheffield city centre[7].

3.14.2 Implementation costs

3.14.2.1 Capital costs

The main capital costs associated with implementing speed restriction measures on motorways consist of the costs of installing the necessary camera enforcement network. A low cost option (known as Truvelo cameras) and a high cost option (SPECS digital cameras) are available. Information supplied by the Highways Agency indicates that it would cost approximately £700,000 to equip a 12 km stretch of the M1 with Truvelo cameras, or £4.8 million to equip the same stretch with SPECS cameras. It has been assumed that a total of eight stretches of motorway would need to be fitted with enforcement cameras in order to implement a revised speed policy on motorway sections close to urban areas, hence the costs of equipping a 12 km stretch of the M1 have been multiplied up by a factor of eight. The estimated total and annualised costs of installing such camera systems on eight stretches of motorway across the UK are presented below; the camera equipment has been assumed to have a lifetime of 15 years and the capital costs have been discounted appropriately to provide annualised cost estimates. It should be stressed that in practice, the costs for each urban area would differ, as the length of speed-restricted motorway would be different for each urban area. However, it is beyond the scope of this study to identify the specific sections and lengths of motorway that should be included in such a scheme. Any further work on this option would need to consider this issue in much greater detail.

Table 3.127: Estimated total and annualised costs of equipping eight 12 km sections of motorway with speed enforcement cameras

	Total cost (£millions)	Annualised cost (£millions)
Costs of enforcement camera (Low cost option - Truvelo cameras)	£5.60	£0.49
Costs of enforcement camera (High cost option - SPECS cameras)	£38.40	£3.33

Table 3.128: Net Present Value of scheme set-up costs over the period between 2005 and 2010

	NPV of set-up costs (2005-2010)
Truvelo cameras (low cost estimate)	£2.92 million
SPECS cameras	£20.00 million

3.14.2.2 Operating costs

No information was available on the operating costs associated with motorway speed restriction schemes, although it is thought that costs would be low, and for the purposes of this study, they have been assumed to be zero.

3.14.3 Emissions abatement performance

The reduction in NOx and PM_{10} emissions due to the introduction of motorway speed restrictions has been estimated by using the results of previous emissions modelling that was carried out to estimate the emissions impact of introducing such a scheme on a section of the M1 near

Sheffield[7]. To estimate the impact on emissions for the eight largest urban areas outside London, it has been assumed that schemes in other urban areas would lead to the same reduction in emissions as the scheme modelled for Sheffield. Whilst this is a gross simplification of what would actually happen, it is not possible to provide an estimate of the total emissions abatement performance for all eight urban areas without carrying out very detailed emissions modelling. Estimates of the NOx and PM_{10} emissions abatement performance using this simplified methodology are presented in Table 3.129 and Table 3.130. Any further work carried out on this option would need to consider individual locations in more detail.

Table 3.129: Estimated reduction in total NOx emissions from road transport due to the implementation of the reduced speed limit (50 mph) on sections of motorway close to urban areas

NOx emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total NOx emissions from road transport	572.20	534.52	495.15	457.12	417.81	384.37	2861.18
Estimated total NOx emissions with motorway speed restrictions in place	570.28	532.72	493.48	455.58	416.41	383.07	2851.54
Emissions abatement against baseline	**-1.93**	**-1.80**	**-1.67**	**-1.54**	**-1.41**	**-1.30**	**-9.64**
Percentage reduction against baseline	**-0.34%**	**-0.34%**	**-0.34%**	**-0.34%**	**-0.34%**	**-0.34%**	**-0.34%**

Table 3.130: Estimated reduction in total PM_{10} emissions from road transport due to the implementation of the reduced speed limit (50 mph) on sections of motorway close to urban areas

PM_{10} emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total PM_{10} emissions from road transport	25.59	24.16	22.40	20.70	19.14	17.83	129.82
Estimated total PM_{10} emissions with motorway speed restrictions in place	25.57	24.14	22.39	20.69	19.13	17.82	129.73
Emissions abatement against baseline	**-0.02**	**-0.02**	**-0.02**	**-0.01**	**-0.01**	**-0.01**	**-0.09**
Percentage reduction against baseline	**-0.07%**	**-0.07%**	**-0.07%**	**-0.07%**	**-0.07%**	**-0.07%**	**-0.07%**

3.14.4 Qualitative assessment of wider impacts

Table 3.131: Assessment of the wider impacts of reduced speed limits on motorways

Performance criteria	Qualitative score
Carbon monoxide emissions	1
Hydrocarbon emissions	1
Ground level ozone	1
Noise	2
Congestion	-1
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	0
Public/industry acceptability	-3
Practicality	-3

3.15 Car clubs

3.15.1 Deployment scenario

Information from CarPlus, the association for UK car clubs, has indicated that there were approximately 250 car club cars operating in the UK in September 2004. CarPlus has indicated that it would be possible for these numbers to increase to 1000 cars by 2010. This has been used as the target scenario, with gradual increases in the number of car club cars in operation in each year from 2005 to 2010. The assumed rate of increase in the number of car club cars between 2005 and 2010 is presented below in Table 3.132.

Table 3.132: Projected total number of car club cars between 2005 and 2010

	2004	2005	2006	2007	2008	2009	2010
Projected number of car club cars	250	375	500	625	750	875	1000

3.15.2 Implementation costs

3.15.2.1 Capital costs

The bulk of the capital costs associated with increasing the number of car clubs relates to the purchase of additional vehicles. It has been assumed that the average value of a car club car is £15,000; car purchase costs have been annualised over a life time of twelve years. Other costs might include security fittings for the vehicles. The unit and annualised costs of car purchase and security costs are presented below in Table 3.133. The net present value of capital costs between 2005 and 2010 associated with increasing the number of car club cars to 1000 is presented in Table 3.134.

Table 3.133: Estimated purchase costs and the costs of fitting additional security devices (unit costs and annualised costs)

	Unit cost	Annualised cost
Average car purchase cost	£15,000	£1,552.26
Security costs	£1,000	£103.48

Table 3.134: Net Present Value of capital costs for increasing the number of car club cars to 1000 by 2010

	NPV of capital costs (2005-2010)
Car clubs	£4.07 million

3.15.2.2 Operating costs

Operating costs include the costs of insuring and taxing the vehicles, along with the costs of staff to run the car clubs. It has been assumed that one full time member of staff is required for every ten car club cars, and that the staff and overhead costs associated with administering and maintaining ten cars comes to £60,000 per year, or £6,000 per car per year. Other costs include the cost of insurance and Vehicle Excise Duty. Details of the estimated unit operating costs per additional car club car are given below in Table 3.135. The net present value of additional operating costs between 2005 and 2010 for all of the additional car club cars is presented in Table 3.136.

Table 3.135: Estimated unit operating costs per additional car club car

	Operating costs per car per year
Staff and overheads	£6,000
Insurance and Vehicle Excise Duty	£1,180
Total estimated annual operating costs	**£7,180**

Table 3.136: Net Present Value of additional operating costs for increasing the number of car club cars to 1000 by 2010

	NPV of operating costs (2005-2010)
Car clubs	£17.46 million

3.15.3 Emissions abatement performance

The total reduction in emissions due to an increase in the number of car clubs has been estimated based on the assumption that each person that joins a car club reduces their annual vehicle mileage by 4,500 miles per year, and that an average of 20 people use each car club car. Reductions in NOx, PM_{10}, and CO_2 emissions are therefore due to a reduction in the total number of vehicle kilometres travelled each year. The following tables provide initial estimates for the impact that an increase in the number of car clubs would have on total road transport emissions

Table 3.137: Estimated reduction in total NOx emissions from road transport due to the increase in the number of car clubs

NOx emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total NOx emissions from road transport	572.20	534.52	495.15	457.12	417.81	384.37	2861.18
Estimated total NOx emissions with increased number of car clubs	572.18	534.49	495.12	457.08	417.78	384.33	2860.97
Emissions abatement against baseline	**-0.03**	**-0.03**	**-0.03**	**-0.04**	**-0.04**	**-0.04**	**-0.21**
Percentage reduction against baseline	**0.00%**	**-0.01%**	**-0.01%**	**-0.01%**	**-0.01%**	**-0.01%**	**-0.01%**

Table 3.138: Estimated reduction in total PM_{10} emissions from road transport due to the increase in the number of car clubs

PM_{10} emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Baseline total PM_{10} emissions from road transport	25.59	24.16	22.40	20.70	19.14	17.83	129.82
Estimated total PM_{10} emissions with increased number of car clubs	25.59	24.16	22.40	20.70	19.14	17.83	129.82
Emissions abatement against baseline	**0.000**	**-0.001**	**-0.001**	**-0.001**	**-0.001**	**-0.001**	**-0.004**
Percentage reduction against baseline	**-0.002%**	**-0.002%**	**-0.003%**	**-0.004%**	**-0.004%**	**-0.005%**	**-0.003%**

Table 3.139: Estimated reduction in total CO_2 emissions from road transport due to the increase in the number of car clubs

CO_2 emissions (kilotonnes)	2005	2006	2007	2008	2009	2010	Total (2005-2010)
Estimated change in CO_2 emissions due to increaseed number of car clubs	-10.50	-14.00	-17.50	-21.00	-24.50	-28.00	-115.50

3.15.4 Qualitative assessment of wider impacts

Table 3.140: Assessment of the wider impacts of increased numbers of car clubs

Performance criteria	Qualitative score
Carbon monoxide emissions	1
Hydrocarbon emissions	1
Ground level ozone	1
Noise	0
Congestion	1
Accident rate	0
Social cohesion	1
Quality of life	2
Distribution effects	1
Public/industry acceptability	-1
Practicality	-1

4 Options for the 2011 to 2025 time period

4.1 Overview

For the 2011 to 2025 time period, detailed datasets for all options are not necessarily available, and it has not been possible to carry out detailed modelling for all options. Where it has been possible, some estimates of the effects that options would have on baseline NOx and PM_{10} emissions have been made and the results of these analyses have been included in this report. For all options, whether or not emissions abatement estimates are available, a qualitative assessment of the likely effects of each option on NOx and PM_{10} emissions has been provided. The main reason for providing such qualitative assessments is that this data can be used in the Multi-Criteria Analysis process to help rank and prioritise the options for further investigation.

No attempt has been made to provide detailed cost estimates of all of the options, primarily due to a lack of robust data. Again, qualitative assessments of the likely capital and operating costs associated with each option have been made using the +3 to –3 scoring system described and used in the analysis of options for the 2005 to 2010 time period. The wider impacts of options for the 2011-2025 time period were scored in the same manner as previously carried out for the 2005-2010 time period.

4.2 Battery powered electric vehicles

4.2.1 Deployment scenario

The scenario examined for this option assumes that battery technology develops over the next few years to the point where increased vehicle range and reduced costs mean that the option is viable for more extensive use in light and heavy-duty vehicle applications. The deployment scenario assumes a relatively slow uptake of the technology with 10% of the heavy duty vehicle fleet operating on battery-electric technology by 2025.

4.2.2 Implementation costs

Quantified estimates of the capital and operating costs associated with this option are currently unavailable.

4.2.3 Emissions abatement performance

Although there are no point-of-use vehicle emissions, the emissions released at power stations due to the electricity used to recharge the batteries of electric vehicles must be taken into account. Initial estimates indicate that, based on the current electricity generating mix, NOx emissions per vehicle kilometre from battery electric vehicles would decrease by 52%, and PM_{10} emissions would decrease by 66%.

Table 4.1: Estimated reduction in total NOx emissions from road transport due to increased uptake of battery-electric vehicles

NOx emissions (kilotonnes)	**2011**	**2015**	**2020**	**2025**	**Total (2011-2025)**
Baseline total NOx emissions from road transport	357.04	291.43	279.95	294.60	4,444.03
Estimated total NOx emissions assuming 10% of heavy duty vehicle fleet are battery-electric vehicles by 2025	356.47	289.26	275.95	288.23	4,393.94
Emissions abatement against baseline	**-0.57**	**-2.16**	**-4.00**	**-6.37**	**-50.09**
Percentage reduction against baseline	**-0.16%**	**-0.74%**	**-1.43%**	**-2.16%**	**-1.13%**

Table 4.2: Estimated reduction in total PM_{10} emissions from road transport due to increased uptake of battery-electric vehicles

PM_{10} emissions (kilotonnes)	**2011**	**2015**	**2020**	**2025**	**Total (2011-2025)**
Baseline total PM_{10} emissions from road transport	16.68	14.21	14.34	15.42	221.68
Estimated total PM_{10} emissions assuming 10% of heavy duty vehicle fleet are battery-electric vehicles by 2025	16.67	14.17	14.27	15.31	220.80
Emissions abatement against baseline	**-0.013**	**-0.040**	**-0.069**	**-0.110**	**-0.884**
Percentage reduction against baseline	**-0.08%**	**-0.28%**	**-0.48%**	**-0.71%**	**-0.40%**

4.2.4 Qualitative assessment of costs, emissions abatement performance and wider impacts

An accurate estimate of the costs of this technology for future years is not available and for this reason a qualitative assessment of the capital and operating costs has been made, along with an assessment of the impacts on emissions and the wider impacts of increased uptake of battery-electric vehicle technology.

Table 4.3: Assessment of the costs, emissions performance and wider impacts of increased uptake of battery electric vehicles

Performance criteria	Qualitative score
Capital costs	-2
Operating costs	0
NOx emissions	2
PM_{10} emissions	2
Carbon monoxide emissions	2
Hydrocarbon emissions	2
Ground level ozone	2
CO_2 emissions	2
Noise	3
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	0
Public/industry acceptability	-1
Practicality	-1

4.3 Hydrogen fuel cell powered vehicles for captive fleets

4.3.1 Deployment scenario

Between 2011 and 2025, it is likely that early production versions of hydrogen fuel cell-powered vehicles will become available, although the costs associated with such vehicles are still likely to be higher than conventional petrol and diesel vehicles. Whilst it is unlikely that there will be widespread public availability of fuel cell passenger cars in this time period, the first captive fleets of such vehicles (including passenger cars, light vans, and possibly some heavy duty vehicles such as buses) may appear. Captive fleets would be necessary as an initial means of overcoming the need for a completely new refuelling infrastructure; such fleets would operate on a limited route, with restricted mileages, and would refuel at a depot.

4.3.2 Implementation costs

Estimates of the capital and operating costs associated with this option are currently not available. A qualitative assessment of the costs of this option can be found in Section 4.3.4.

4.3.3 Emissions abatement performance

Quantified estimates of the reduction in NOx and PM_{10} emissions related to the uptake of fuel cell powered vehicles in captive fleets are currently not available. Qualitative assessments of emissions abatement performance are presented in Section 4.3.4.

4.3.4 Qualitative assessment of costs, emissions abatement performance and wider impacts

Table 4.4 presents a qualitative assessment of the cost implications, emissions abatement performance and wider impacts associated with using fuel cell vehicles in captive fleets.

Table 4.4: Assessment of the costs, emissions performance and wider impacts of increased uptake of fuel cell vehicles in captive fleets

Performance criteria	Qualitative score
Capital costs	-3
Operating costs	-1
NOx emissions	2
PM_{10} emissions	2
Carbon monoxide emissions	2
Hydrocarbon emissions	2
Ground level ozone	2
CO_2 emissions	1
Noise	3
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	0
Public/industry acceptability	-3
Practicality	-2

4.4 New diesel formulations

4.4.1 Deployment scenario

Work carried out as part of the Auto Oil II programme[15] identified that altering the physical and chemical properties of diesel fuel could lead to large reductions in emissions of particulate matter. Based on modelling work carried out during this research programme, fuel properties including fuel density, distillation end point, and percentage content of polyaromatic compounds were found to have an influence on emissions of particulates. The effects on particulate emissions were most pronounced for light duty vehicles, with potential reductions of between 4 and 20%, depending on the particular fuel specification modelled. For heavy duty vehicles, estimated particulate emission reductions were found to be much lower, ranging from 0.2% to 3.1%. For this scenario, it has been assumed that after 2011, new formulations of diesel could be brought into widespread use.

4.4.2 Implementation costs

No data is currently available to provide quantified estimates of the costs associated with new low emission diesel formulations.

4.4.3 Emissions abatement performance

It has been assumed that new diesel formulations would not have any effect on NOx emissions, but would contribute to a reduction in PM_{10} emissions. A 4% reduction in PM_{10} emissions has been assumed.

Table 4.5: Estimated reduction in total PM_{10} emissions from road transport due to the new low emission diesel formulations

PM_{10} emissions (kilotonnes)	2011	2015	2020	2025	Total (2011-2025)
Baseline total PM_{10} emissions from road transport	16.68	14.21	14.34	15.42	221.68
Estimated total PM_{10} emissions due to new diesel formulations	16.32	13.91	14.04	15.10	218.52
Emissions abatement against baseline	**-0.36**	**-0.30**	**-0.30**	**-0.32**	**-3.16**
Percentage reduction against baseline	**-2.17%**	**-2.11%**	**-2.08%**	**-2.10%**	**-1.43%**

4.4.4 Qualitative assessment of costs, emissions abatement performance and wider impacts

Table 4.6 presents a qualitative assessment of the cost implications, emissions abatement performance and wider impacts associated with using fuel cell vehicles in captive fleets.

Table 4.6: Assessment of the costs, emissions performance and wider impacts of new diesel formulations

Performance criteria	Qualitative score
Capital costs	-1
Operating costs	1
NOx emissions	0
PM_{10} emissions	2
Carbon monoxide emissions	0
Hydrocarbon emissions	0
Ground level ozone	0
CO_2 emissions	1
Noise	0
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	0
Public/industry acceptability	3
Practicality	3

4.5 Scrappage incentive scheme for Euro 2, Euro 3, and Euro 4 vehicles

4.5.1 Deployment scenario

Between 2011 and 2025 scrappage schemes could be implemented to accelerate the disposal of Euro 2, Euro 3 and Euro 4 vehicles. As with the incentive scheme for pre-Euro and Euro 1 vehicles discussed in Section 3.9, this would involve providing owners of the eligible vehicles with a financial incentive to dispose of their cars earlier than they otherwise would have done.

The emissions benefits of scrappage schemes for Euro 2, Euro 3 and Euro 4 vehicles will depend to a large part on the relative emissions performance of such vehicles when compared to post-Euro 4 vehicles. As the standards for post Euro 4 light duty vehicles have not been finalised, it is difficult to assess what the emissions implications of such a scrappage scheme would be. However, it is thought likely that scrappage schemes targeting Euro 2, Euro 3, and Euro 4 vehicles will not have as great an effect on total NO_x and particulate emissions as a scrappage scheme introduced between 2005 and 2010 targeting pre-Euro and Euro 1 vehicles would have.

4.5.2 Implementation costs

No quantified estimates of the costs of implementing and operating a scrappage scheme for Euro 2, 3 and 4 vehicles are available, although it is likely that the costs would be similar to those incurred by a scheme aimed at pre-Euro and Euro 1 vehicles.

4.5.3 Emissions abatement performance

Quantified estimates of the emissions reductions that would occur from implementing a scrappage incentive scheme targeting Euro 2, Euro 3, and Euro 4 vehicles are not currently available.

4.5.4 Qualitative assessment of costs, emissions abatement performance and wider impacts

A qualitative assessment of the likely costs, emissions benefits, and wider impacts of scrappage incentive schemes for Euro 2, 3, and 4 vehicles can be found in Table 4.7.

Table 4.7: Assessment of the costs, emissions performance and wider impacts of scrappage incentive schemes for Euro 2, Euro 3 and Euro 4 vehicles

Performance criteria	Qualitative score
Capital costs	1
Operating costs	-2
NOx emissions	1
PM_{10} emissions	1
Carbon monoxide emissions	1
Hydrocarbon emissions	1
Ground level ozone	1
CO_2 emissions	0
Noise	0
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	-1
Public/industry acceptability	-1
Practicality	-3

4.6 National road pricing scheme for all vehicles

4.6.1 Deployment scenario

In 2004, the Department for Transport published the results of a study into the feasibility of implementing a national road pricing scheme[13]**.** The study concluded that such a scheme would require on-board vehicle data collection units that would be able to determine how far, when, and where an individual vehicle had travelled. It is not thought that such equipment would be available in a low-cost, mass-produced form until 2014 at the earliest. The scenario that has been developed for this study is based on implementing a national road-pricing scheme in 2015, using assumptions from modelling carried out by the Department for Transport as to the effect that the scheme would have on vehicle traffic. As part of the feasibility study into a national road-pricing scheme, several scenarios have been developed with estimates of the likely effects of each scenario on vehicle traffic. The deployment scenario assumed for this analysis is based on the scheme leading to a 3% reduction across all roads in total annual vehicle kilometres travelled by all vehicles, including a 6% reduction on urban roads. These percentage reductions in vehicle kilometres have been applied to projections for future total vehicle kilometres in each year between 2015 and 2025, and this data has been used as the basis for estimating the effect of road user charging on NOx and PM_{10} emissions. It should be noted that the DfT feasibility study provided an initial assessment of the likely traffic impacts of a number of different national road user charging scheme scenarios. Within the scope of this work, it has only been possible to provide information on likely emissions benefits for one scenario.

4.6.2 Implementation costs

Detailed and accurate estimates of the costs of setting up and operating a national road-pricing scheme are not available at this point in time, due in particular to uncertainties in the costs of the technology that would be used to monitor vehicle movements. However, the Department for

Transport has published the results of research that provide initial estimates of the range of likely set-up and operation costs. The findings from this research are presented in the following sections

4.6.2.1 Set-up costs

Set up costs would be dominated by the costs of equipping all vehicles in the UK with on-board vehicle data collection units (OBUs). These OBUs would be used to monitor and report on vehicle movements, thereby enabling charges to be applied. As the future costs of such units are unknown, two costs estimates were prepared, based on equipment purchase costs of £100 and £525 per unit respectively. The total cost estimates assume that there are 30 million vehicles in the national fleet, and includes the costs of fitting the OBUs to vehicles.

Table 4.8: Estimated costs of equipping all vehicles with on-board monitoring units

Estimated OBU unit costs	Total costs of equipping all vehicles in the UK with OBUs (includes fitting costs)
£100 per unit	£10,000 million
£525 per unit	£27,000 million

Other costs associated with setting up a national road-pricing scheme include the costs of roadside enforcement equipment, and the cost of procuring/setting up the administrative support structures (e.g. billing, data support, and call centres, etc). The one-off costs associated with these items are presented below.

Table 4.9: Estimated additional set-up costs for a national road-pricing scheme

Additional scheme set-up costs	
Roadside enforcement equipment	£20 million
Administrative support structures	£500 million

The Net Present Value of set-up costs between 2011 and 2025 can be estimated by annualising the capital and set-up costs described above; the costs of equipping all vehicles with OBUs have been annualised over seven years. This is based on the current average age of passenger cars in the UK and the average total lifetime of such vehicles; the average age of a typical passenger car is 6.6 years[16], and the average lifetime of a passenger car is 13.9 years[17]. Hence the average remaining useful life of vehicles to be fitted with OBUs is approximately seven years. The costs of roadside enforcement equipment and administrative support structure have been annualised over a period of 20 years. Table 4.10 gives the Net Present Value of costs between 2011 and 2025 for setting up a national road pricing scheme; as might be expected the estimated costs are very high, ranging from £11.9 billion to £31.3 billion.

Table 4.10: Net Present Value (2011-2025) of set up costs for a national road pricing scheme

	NPV of set-up costs (2011-2025)
Road pricing scheme (low cost estimate)	£11,851 million
Road pricing scheme (high cost estimate)	£31,312 million

4.6.2.2 Operating costs
The results of the DfT commissioned research into the costs of a national road pricing scheme indicated that three main elements would dominate the operating costs associated with such a scheme. These are as follows:

- The costs of telecommunications between OBUs and the administrative back-office
- Back-office administrative processing operations (e.g. customer registration, billing, payment collection)
- Enforcement costs

Telecommunication costs are based on the need to bulk purchase capacity to allow communication between vehicle OBUs and the back office. Estimates of the total have been based on a price of £36 per vehicle per year, although it should be noted that in future years these costs may decrease. Back-office administrative costs are based on typical staffing requirements, average industry wages and the costs of premises and maintenance. Enforcement costs were estimated on the basis of using Automatic Number Plate Recognition (ANPR) camera technology as the means by which to detect those evading the charge. Table 4.11 below provides a summary of the estimated costs associated with each of these elements, as originally identified in the Road Pricing Feasibility Study.

Table 4.11: Estimated annual operating costs associated with a national road pricing scheme for the UK

Annual operating costs	
Telecommunications costs	£1,000 million
Administrative support costs	£845 million
Enforcement costs	£273 million

Based on these figures, the Net Present Value of operating costs over the period 2011 to 2025 has been calculated. This figure is presented in Table 4.12.

Table 4.12: Net Present Value (2011-2025) of operating costs for a national road pricing scheme

	NPV of operating costs (2011-2025)
Road pricing scheme	£23,816 million

4.6.3 Emissions abatement performance
The reductions in NOx and PM_{10} emissions have been calculated for each year between 2015 and 2025 based on a reduction of 3% in total annual vehicles kilometres (3.6% reduction for passenger cars, 0.9% reduction for light goods vehicles, and 0.3% reduction for HGVs). These figures were supplied by the Department for Transport, and were used by Netcen to model the effect of a national road pricing scheme on NOx and PM_{10} emissions from transport. The results of this modelling work are presented below.

Table 4.13: Estimated reduction in total NOx emissions from road transport due to the introduction of a national road pricing scheme in 2015

NOx emissions (kilotonnes)	2011	2015	2020	2025	Total (2011-2025)
Baseline total NOx emissions from road transport	357.04	291.43	279.95	294.60	4,444.03
Estimated total NOx emissions with additional bus priority schemes in place	357.04	286.93	275.47	289.94	4,394.36
Emissions abatement against baseline	**0.00**	**-4.50**	**-4.48**	**-4.66**	**-49.67**
Percentage reduction against baseline	**0.00%**	**-1.54%**	**-1.60%**	**-1.58%**	**-1.12%**

Table 4.14: Estimated reduction in total PM_{10} emissions from road transport due to the introduction of a national road pricing scheme in 2015

PM_{10} emissions (kilotonnes)	2011	2015	2020	2025	Total (2011-2025)
Baseline total PM_{10} emissions from road transport	16.68	14.21	14.34	15.42	221.68
Estimated total PM_{10} emissions with additional bus priority schemes in place	16.68	13.98	14.10	15.17	219.10
Emissions abatement against baseline	**0.00**	**-0.23**	**-0.23**	**-0.25**	**-2.58**
Percentage reduction against baseline	**0.00%**	**-1.60%**	**-1.63%**	**-1.60%**	**-1.17%**

4.6.4 Qualitative assessment of costs, emissions abatement performance and wider impacts

Table 4.15 provides details of the qualitative assessment of the costs, emissions abatement performance, and wider impacts of implementing a UK-wide road pricing scheme.

Table 4.15: Assessment of the costs, emissions performance and wider impacts of a national road pricing scheme

Performance criteria	Qualitative score
Capital costs	-3
Operating costs	-3
NOx emissions	2
PM_{10} emissions	2
Carbon monoxide emissions	1
Hydrocarbon emissions	1
Ground level ozone	1
CO_2 emissions	2
Noise	0
Congestion	2
Accident rate	1
Social cohesion	2
Quality of life	1
Distribution effects	-1
Public/industry acceptability	-3
Practicality	-1

4.7 Extended Low Emission Zone schemes

4.7.1 Deployment scenario

Low Emission Zones for London and the next eight largest urban areas were considered as an option for the 2005-2010 time period, and whilst such schemes (based on a minimum standard for heavy duty vehicles of Euro 2 + Reduced Pollution Certificate) would still be effective in reducing NOx and PM_{10} emissions after 2010, their effectiveness will be diminishing as time progresses, and by 2015 there will be no emissions benefits over and above what would have happened without such schemes. In order to further continue the benefits of having Low Emission Zones in place in large urban areas, it would be necessary to alter the minimum vehicle standards at some point between 2010 and 2015; for example the minimum emission standard could be raised to Euro 4. It has not been possible to carry out quantified assessments of the costs or emissions benefits that would accrue from such a measure after 2010, but a qualitative assessment of these aspects, along with the wider impacts of extended LEZ schemes has been carried out.

4.7.2 Implementation costs

No quantified data available.

4.7.3 Emissions abatement performance

No quantified data available.

4.7.4 Qualitative assessment of costs, emissions abatement performance, and wider impacts

A qualitative assessment of the cost implications, emissions performance, and the wider impacts of extended Low Emission Zones is presented below in Table 4.16.

Table 4.16: Assessment of the costs, emissions performance and wider impacts of extended Low Emission Zone schemes

Performance criteria	Qualitative score
Capital costs	-2
Operating costs	-2
NOx emissions	3
PM_{10} emissions	3
Carbon monoxide emissions	3
Hydrocarbon emissions	3
Ground level ozone	2
CO_2 emissions	1
Noise	0
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	-2
Public/industry acceptability	-3
Practicality	-2

4.8 Freight distribution centres and intermodal freight transfer

4.8.1 Deployment scenario

Freight distribution centres with intermodal transfer would enable haulage operators to transfer loads hauled in HGVs over long distances into smaller goods vehicles for the final stages of delivery into urban areas. This measure involves encouraging the construction of transfer centres on the outskirts of cities and towns where goods (carried in inter-modal units) are transferred from heavy-duty vehicles to low-emission light vans (e.g. hybrid-electric, battery-electric, or eventually hydrogen fuel cell powered vans) before being delivered to their final destinations in urban areas. The net effect of this measure would be to reduce HGV traffic and emissions in built-up areas.

It has not been possible to develop a full deployment scenario for this option, as quantitative data is not readily available. However, a qualitative assessment of the potential costs, emissions benefits, and wider impacts has been carried out. In order to fully assess this option, a much more detailed study would be required.

4.8.2 Implementation costs

No quantified cost data is available for this option. A qualitative assessment of capital and operating costs is provided in Section 4.8.4.

4.8.3 Emissions abatement performance

Quantified estimates of the reductions in NOx and PM_{10} emissions associated with this option are not currently available. A qualitative assessment of emissions abatement performance has been provided in Section 4.8.4.

4.8.4 Qualitative assessment of costs, emissions abatement performance and wider impacts

A qualitative assessment of the costs, emissions performance and wider impacts of this option is presented below.

Table 4.17: Assessment of the costs, emissions performance and wider impacts of further integrated land use and transport planning

Performance criteria	Qualitative score
Capital costs	-2
Operating costs	-1
NOx emissions	1
PM_{10} emissions	1
Carbon monoxide emissions	1
Hydrocarbon emissions	1
Ground level ozone	1
CO_2 emissions	1
Noise	1
Congestion	1
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	0
Public/industry acceptability	-1
Practicality	-1

4.9 Further integrated land use and transport planning

4.9.1 Deployment scenario

In the medium term, land use and transport planning can be further integrated by policies in both fields aiming to reduce private vehicle use or reduce the need to travel between locations altogether. Land use planning has a wide impact on transport, which is currently taken into account in planning applications. This current policy can be further strengthened to reduce private traffic, and land use mixes can be designed to ensure that people can live nearer their place of work.

Integration possibilities include:

- further promotion and development of mixed land-use areas
- redevelopment of industry, retail and entertainment in inner cities
- development of public transport possibilities alongside new residential or industrial areas or vice versa
- extension of current parking restrictions (maximum parking standards)

The effects of closer co-ordination between land use and transport policies on emission levels are difficult to estimate. Societal trends such as the likelihood of two people in each household being employed, and the tendency to work further away from home make behavioural change as a result of land use policy, and resulting emissions changes, very difficult to predict.

4.9.2 Implementation costs
No data is currently available.

4.9.3 Emissions abatement performance
No data is currently available.

4.9.4 Qualitative assessment of costs, emissions abatement performance and wider impacts
A qualitative assessment of the costs, emissions performance and wider impacts of this option are presented below.

Table 4.18: Assessment of the costs, emissions performance and wider impacts of further integrated land use and transport planning

Performance criteria	Qualitative score
Capital costs	0
Operating costs	-1
NOx emissions	1
PM_{10} emissions	1
Carbon monoxide emissions	1
Hydrocarbon emissions	1
Ground level ozone	1
CO_2 emissions	1
Noise	0
Congestion	1
Accident rate	0
Social cohesion	1
Quality of life	2
Distribution effects	0
Public/industry acceptability	1
Practicality	-2

4.10 Dynamic route planning

4.10.1 Deployment scenario
On-board vehicle navigation tools could be integrated with central information systems to reduce emissions in urban centres. In particular, such a measure could be used to counteract short-term local air quality problems. The navigation system would receive up-to-date air quality information for a local area (e.g. from local air pollution monitoring stations) in order to reroute the vehicle away from any pollution hotspots. Such a measure may not lead to reductions in total emissions, as alternative routes proposed by the navigation system may be longer than the original route, and hence overall emissions of NO_x and particulate emissions could, in theory, be higher. However, the main aim of such a system would not be to reduce overall emissions, but to reduce emissions (and thereby improve air quality) in highly sensitive areas. If the navigation system receives a signal that there is a short-term local air quality problem, vehicles would only be redirected for as long as the pollutant concentrations remain high. Once pollutant concentrations drop back to acceptable levels, the navigation system would stop proposing alternative routes.

It must be noted that whilst such a measure would allow alternative routes to be proposed to the vehicle's driver, the final decision on whether to use the proposed alternative route will ultimately rest with the driver. The navigation system will not be able to force the driver to take the proposed route, and with this in mind, such a system should be seen as a form of information provision.

4.10.2 Implementation costs

No quantified estimates are currently available regarding the set-up and operating costs associated with this scenario option.

4.10.3 Emissions abatement performance

Estimates of the effect of this option on NOx and PM_{10} emissions are not currently available. However, it should be noted that the aim of the option would be to reduce population exposure to pollutant emissions, and hence it is possible that total emissions may increase.

4.10.4 Qualitative assessment of costs, emissions abatement performance and wider impacts

A qualitative assessment of the costs, emissions performance and wider impacts of this option are presented below.

Table 4.19: Assessment of the costs, emissions performance and wider impacts of dynamic route planning systems

Performance criteria	Qualitative score
Capital costs	-1
Operating costs	-1
NOx emissions	1
PM_{10} emissions	1
Carbon monoxide emissions	1
Hydrocarbon emissions	1
Ground level ozone	1
CO_2 emissions	0
Noise	0
Congestion	1
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	0
Public/industry acceptability	1
Practicality	1

4.11 Emissions trading schemes for heavy duty vehicles and taxis

4.11.1 Deployment scenario

An Emissions Trading Scheme (ETS) could be introduced in the road transport sector for heavy-duty vehicles and taxis. The principle would be the same as for the industrial sector (i.e. participants would be allocated emissions allowances) and to simplify matters, it could also be based on CO_2 emissions rather than local air pollutants. In the same fashion as the industrial ETS, participating vehicle operators would each be issued an annual CO_2 emissions allocation, and those that wish to emit in excess of these allocations would be able to purchase an additional allocation from those who have a surplus. As with the industrial Emissions Trading Scheme, the total amount of allowances would be fixed. Whilst the main driver of such a scheme would be CO_2 emissions reductions, there could also be reductions in emissions of local air pollutants such as NO_x and particulates due to reductions in overall vehicle kilometres.

4.11.2 Implementation costs

No data currently available.

4.11.3 Emissions abatement performance

No data currently available.

4.11.4 Qualitative assessment of costs, emissions abatement performance and wider impacts

A qualitative assessment of the costs, emissions performance and wider impacts of this option are presented below.

Table 4.20: Assessment of the costs, emissions performance and wider impacts of an emissions trading scheme for HGVs and taxis

Performance criteria	Qualitative score
Capital costs	0
Operating costs	-1
NOx emissions	1
PM_{10} emissions	1
Carbon monoxide emissions	1
Hydrocarbon emissions	1
Ground level ozone	1
CO_2 emissions	2
Noise	0
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	0
Distribution effects	-3
Public/industry acceptability	-3
Practicality	-2

4.12 Personal carbon accounts

4.12.1 Deployment scenario

Personal Carbon Accounts can be thought of as an extension to Emissions Trading Schemes. In such a scenario, every individual would be allocated an annual allowance of carbon emissions (a “carbon account”). As with the ETS, individuals who want or need to exceed their personal annual allowance would be able to purchase carbon credits from those that have a surplus. Such a scheme would also lead to reductions in emissions of local air pollutants.

4.12.2 Implementation costs
No data currently available.

4.12.3 Emissions abatement performance
No data currently available.

4.12.4 Qualitative assessment of costs, emissions abatement performance and wider impacts
A qualitative assessment of the costs, emissions performance and wider impacts of personal carbon accounts are presented below.

Table 4.21: Assessment of the costs, emissions performance and wider impacts of personal carbon accounts

Performance criteria	Qualitative score
Capital costs	0
Operating costs	-2
NOx emissions	1
PM_{10} emissions	1
Carbon monoxide emissions	1
Hydrocarbon emissions	1
Ground level ozone	1
CO_2 emissions	2
Noise	0
Congestion	1
Accident rate	0
Social cohesion	0
Quality of life	0
Distribution effects	0
Public/industry acceptability	-3
Practicality	-2

5 Options for the 2025 to 2050 time period

5.1 Overview

For the 2025 to 2050 time period, no quantified estimates of the costs and emissions abatement performance of different scenario options are available, and no attempt has been made to try to quantify these figures, as there are too many unknowns to deal with over such a distant time period. Instead, the assessment of scenario options has focused on providing qualitative scores for each of the performance criteria for use in a Multi-Criteria Analysis that will allow options to be prioritised for further investigation.

5.2 Large scale uptake of hydrogen fuel cell passenger cars

5.2.1 Deployment scenario

Over the period 2020 to 2050, there are likely to be significant increases in the amount of fuel cell vehicles on the road, and an optimistic estimate for 2050 would be that 50% of the vehicle parc consists of fuel cell powered vehicles. Uptake of hydrogen fuel-cell vehicles is likely to be dependent on a number of factors including the following: availability of vehicles at a price that is competitive with other technologies, availability of a fuel supply infrastructure, costs of hydrogen, and political support for moving to a hydrogen-based economy.

5.2.2 Implementation costs

No data available.

5.2.3 Emissions abatement performance

No data available.

5.2.4 Qualitative assessment of costs, emissions abatement performance and wider impacts

A qualitative assessment of the costs, emissions performance and wider impacts of large scale uptake of hydrogen fuel cell passenger cars is presented below.

Table 5.1: Assessment of the costs, emissions performance and wider impacts of the large-scale uptake of hydrogen fuel cell passenger cars

Performance criteria	Qualitative score
Capital costs	0
Operating costs	0
NOx emissions	3
PM_{10} emissions	3
Carbon monoxide emissions	3
Hydrocarbon emissions	3
Ground level ozone	3
CO_2 emissions	3
Noise	0
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	1
Public/industry acceptability	0
Practicality	0

5.3 Automated highways

5.3.1 Deployment scenario

Co-ordination of individual vehicle movements on an automated highway could both increase the capacity of roads and decrease emissions related to road transport. As cars join the motorway, control of their movements would be taken over by an automated system. This would allow for closer vehicle spacing and more constant speeds, enhancing traffic capacity and reducing emissions resulting from variable driving speeds and inefficient traffic flows. Automation would be effected through a combination of sensor, computer and communications systems in vehicles and along the roadway.

A study sponsored by the National Automated Highway System Research Program in the USA estimated that vehicles functioning on such highways could reduce fuel use by up to 25% per vehicle mile[18]. There are, however, various barriers to the introduction of Automated Highway technology. The feasibility of implementing automated systems that are tolerant to technical and human failure is questionable. There are also concerns about the secondary effects that these systems might have, as substantial increases in road capacity are likely to result from such schemes (due to a reduction in the average distance between vehicles) and resulting higher emissions. However, this would not necessarily be a problem if there was widespread use of hydrogen fuel cell vehicles.

5.3.2 Implementation costs

No data available.

5.3.3 Emissions abatement performance

No data available.

5.3.4 Qualitative assessment of costs, emissions performance and wider impacts

A qualitative assessment of the costs, emissions performance and wider impacts of large scale uptake of automated highway schemes is presented below.

Table 5.2: Assessment of the costs, emissions performance and wider impacts of automated highways

Performance criteria	Qualitative score
Capital costs	-2
Operating costs	-2
NOx emissions	1
PM_{10} emissions	1
Carbon monoxide emissions	1
Hydrocarbon emissions	1
Ground level ozone	1
CO_2 emissions	1
Noise	0
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	2
Distribution effects	2
Public/industry acceptability	-2
Practicality	-2

5.4 Complete substitution of petrol and diesel by biofuels

5.4.1 Deployment scenario

During the period covering 2025 to 2050, it could be envisaged that petrol and diesel might be completely replaced by biofuels. In particular, there may be widespread interest in such an option if crude oil production starts to decrease during this time period and there is a consequent significant increase in the price of crude oil.

5.4.2 Implementation costs

No data available.

5.4.3 Emissions abatement performance

It has been assumed that there would not be any reduction in NOx and PM_{10} emissions compared to conventional fuels, although this would be dependent on the specific composition of the biofuels used. Significant reductions in life-cycle CO_2 emissions would be expected.

5.4.4 Qualitative assessment of costs, emissions abatement performance and wider impacts

A qualitative assessment of the costs, emissions performance and wider impacts of large scale uptake of this option is presented below.

Table 5.3: Assessment of the costs, emissions performance and wider impacts of the complete substitution of petrol and diesel by biofuels

Performance criteria	Qualitative score
Capital costs	-1
Operating costs	-1
NOx emissions	0
PM_{10} emissions	0
Carbon monoxide emissions	0
Hydrocarbon emissions	0
Ground level ozone	0
CO_2 emissions	2
Noise	0
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	1
Public/industry acceptability	0
Practicality	0

5.5 Fast moving walkways for short urban journeys

5.5.1 Deployment scenario

Fast moving walkways involve walk-on conveyor belts used to cover a gap in transport facilities for distances too long for walking, but too short to invest in expensive vehicle and infrastructure technologies. The lack of attractive feeders and links in public transport are one of the reasons for excessive car use in cities. Accelerated walkways could play an important role in extending public transport services and making them more attractive. Walkways could be used outside, in central city streets, or as covered walkways between key amenities.

Moving walkways are electrically driven and are free from pollutant emissions at point of use. They are more efficient in energy use compared to conventional passenger vehicles as there are few moving parts. Moving walkways that accelerate at the beginning, operate at constant speed in the middle, and deceleration towards the journey's end-point are already in use at Paris Montparnasse metro station.

5.5.2 Implementation costs

No data available.

5.5.3 Emissions abatement performance

If large enough numbers of people switched from using cars to using moving walkways, then there would be significant reductions in NOx, PM_{10}, and CO_2 emissions.

5.5.4 Qualitative assessment of costs, emissions abatement performance and wider impacts

A qualitative assessment of the costs, emissions performance and wider impacts of large scale uptake of moving walkways is given below.

Table 5.4: Assessment of the costs, emissions performance and wider impacts of fast moving walkways for short urban journeys

Performance criteria	Qualitative score
Capital costs	-3
Operating costs	-2
NOx emissions	1
PM_{10} emissions	1
Carbon monoxide emissions	1
Hydrocarbon emissions	1
Ground level ozone	1
CO_2 emissions	1
Noise	0
Congestion	0
Accident rate	0
Social cohesion	1
Quality of life	1
Distribution effects	1
Public/industry acceptability	1
Practicality	1

5.6 Dedicated road freight systems

5.6.1 Deployment scenario

Dedicated routes for particular modes of transport in cities could increase the efficiency of a particular mode, thereby increasing average speeds and reducing emissions. The measure expands the concept of bus lanes to other modes and opens the possibility of dedicated routes functioning outside the current infrastructure. The use of dedicated modal transport routes would mainly be relevant as a measure for freight, particularly in urban or industrial areas.

Automated Road Freight Systems would consist of dedicated freight lanes (on motorways) to allow automated driving at set speeds. These dedicated lanes would function using the same technology as the automated highway technology.

5.6.2 Implementation costs

The Netherlands' Combi-Road project consists of a dedicated, automated freight track design powered electrically. It is proposed as a means of shuttling freight around the Rotterdam harbour area, one of the busiest ports in Europe covering a considerable area. Investment costs are estimated at £5.1 million per kilometre.

5.6.3 Emissions abatement performance

The advantage of the measure is the potential to reduce pollutant emissions due to more consistent vehicle speeds and more efficient use of road space. Automated road freight systems may also lead to reductions in congestion, accidents, and the costs of transporting goods (mainly through the use of unmanned transport). Precise costs and emission reduction potential are unknown at this point in time.

5.6.4 Qualitative assessment of costs, emissions abatement performance and wider impacts

A qualitative assessment of the costs, emissions performance and wider impacts of dedicated road freight systems is presented below.

Table 5.5: Assessment of the costs, emissions performance and wider impacts of dedicated road freight systems

Performance criteria	Qualitative score
Capital costs	-3
Operating costs	-2
NOx emissions	1
PM_{10} emissions	1
Carbon monoxide emissions	1
Hydrocarbon emissions	1
Ground level ozone	1
CO_2 emissions	1
Noise	0
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	1
Public/industry acceptability	1
Practicality	1

.

5.7 Passenger cars with inter-modal functionality

5.7.1 Deployment scenario

The flexi-train consists of private, light-weight electric cars that are able to join linked convoys behind an engine on main roads and motorways as they travel between major destinations[19]. Cars are then able to separate themselves from the train to travel as separate entities on minor roads and in cities. This concept reduces emissions by using light-weight electric passenger cars in city centres (no emissions at point of use) and a single engine for multiple car users travelling on trunk roads and motorways. The flexi-train also avoids attempting to separate public transport from private, preserving a valued aspect of car driving (personal space) while gaining the benefits of public transport (reduced emissions).

5.7.2 Implementation costs

No data available.

5.7.3 Emissions abatement performance

No data available.

5.7.4 Qualitative assessment of costs, emissions abatement performance and wider impacts

A qualitative assessment of the costs, emissions performance and wider impacts of this option is presented below.

Table 5.6: Assessment of the costs, emissions performance and wider impacts of passenger cars with intermodal functionality

Performance criteria	Qualitative score
Capital costs	-1
Operating costs	-1
NOx emissions	1
PM_{10} emissions	1
Carbon monoxide emissions	1
Hydrocarbon emissions	1
Ground level ozone	1
CO_2 emissions	1
Noise	0
Congestion	0
Accident rate	0
Social cohesion	0
Quality of life	1
Distribution effects	1
Public/industry acceptability	-1
Practicality	-1

5.8 Scrappage scheme for petrol and diesel vehicles

5.8.1 Deployment scenario

It could be envisaged that if at some point during the period 2025-2050, the penetration of hydrogen vehicles rose to high enough levels, it might be feasible to implement a scrappage incentive scheme to accelerate the disposal of petrol and diesel internal combustion engine vehicles. Such a scheme would operate in the same manner as schemes described earlier for pre-Euro/Euro 1 vehicles and for Euro 2, 3, and 4 vehicles.

5.8.2 Implementation costs

No quantified data is currently available, although it would be expected that a similar economic model could be used to the other scrappage schemes described earlier in this report; the owners of eligible vehicles would be entitled to receive a nominal payment for disposing of their vehicles earlier than they otherwise would have done. From the analysis carried out for the pre-Euro/Euro 1 scrappage scheme scenario, the costs of scrappage schemes can be disproportionately high. It might be anticipated that a similar situation would arise for this scrappage scheme as well.

5.8.3 Emissions abatement performance

The emissions abatement performance of the scheme depends to a large degree on how “clean” petrol and diesel vehicles are in future years. There are likely to be some reductions in emissions of NOx, PM_{10}, and CO_2 related to the introduction of the scrappage scheme, but the scale of emissions benefits may be much smaller than what could be achieved in earlier years with an incentive scheme for removing pre-Euro and Euro 1 vehicles from the vehicle parc.

5.8.4 Qualitative assessment of costs, emissions abatement performance and wider impacts

A qualitative assessment of the costs, emissions performance and wider impacts of this option is presented below.

Table 5.7: Assessment of the costs, emissions performance and wider impacts of implementing a scrappage scheme for petrol and diesel vehicles

Performance criteria	Qualitative score
Capital costs	-1
Operating costs	-3
NOx emissions	2
PM_{10} emissions	2
Carbon monoxide emissions	2
Hydrocarbon emissions	2
Ground level ozone	2
CO_2 emissions	2
Noise	1
Congestion	1
Accident rate	1
Social cohesion	0
Quality of life	1
Distribution effects	1
Public/industry acceptability	-1
Practicality	-1

5.9 Fuel duty differential based on life-cycle emissions

5.9.1 Deployment scenario

Under a differential duty system based on life-cycle emissions, fuels with higher emissions of key pollutants would be penalised with higher levels of duty. In practice, this would mean that energy sources such as hydrogen would be taxed at a lower rate than carbon-based fuels such as petrol and diesel. The principle behind this measure would be to encourage the shift to ultra-low emission fuels such as hydrogen, by providing a fiscal incentive to do so.

It is thought likely that such a measure would have a disproportionate effect on those members of society in the lowest income groups. These groups are those that are least likely to be able to afford to purchase (for example) hydrogen-powered vehicles, as they tend to own the oldest (and most polluting) vehicles.

5.9.2 Implementation costs

Unknown.

5.9.3 Emissions abatement performance

No quantified data is available, but this option is likely to lead to reductions in total CO_2 emissions, with additional benefits for NOx and particulate emissions.

5.9.4 Qualitative assessment of costs, emissions abatement performance and wider impacts

A qualitative assessment of the costs, emissions performance and wider impacts of this option is presented below.

Table 5.8: Assessment of the costs, emissions performance and wider impacts of introducing fuel duty differentials based on life-cycle emissions

Performance criteria	**Qualitative score**
Capital costs	0
Operating costs	-1
NOx emissions	2
PM_{10} emissions	2
Carbon monoxide emissions	2
Hydrocarbon emissions	2
Ground level ozone	2
CO_2 emissions	2
Noise	1
Congestion	1
Accident rate	1
Social cohesion	0
Quality of life	1
Distribution effects	-2
Public/industry acceptability	-2
Practicality	-2

6 Multi-criteria analysis of options

6.1 Multi-Criteria Analysis of options for implementation between 2005 and 2010

The analysis of scenarios that was carried out in Chapter 3 can now be used to construct the MCA performance matrix of options for the 2005-2010 time period. The MCA matrix lays out all of the performance data relating to each option so that comparisons can be made. The performance matrix for options that could be implemented between 2005 and 2010 is presented overleaf in Figure 6.1.

At the bottom of the performance matrix, the maximum, minimum, and range values have been calculated for each of the performance criteria. The next step is to use this information to normalise all of the scores for each of the performance criteria (including numerical cost and emissions data) to a scale spanning from 0 to 100, where 0 is the “least preferred” option and 100 relates to the “most preferred” option. The concept of least preferred and most preferred options is important in MCA techniques, as this will form part of the basis by which the options are ranked. Against any given performance criterion, the least preferred option is that which has the most negative effect on that criterion. So, for example, in terms of capital cost, the least preferred option is the one that incurs the greatest cost, i.e. that which has the greatest numerical value attached to it. However, with regard to emissions abatement performance, the least preferred option is the one that gives the lowest reduction in pollutant emissions (options that lead to greater reductions in emissions are obviously more preferred). It should also be noted that some options lead to an *increase* in CO_2 emissions; increases in emissions are less preferred than reductions. The normalised scores for each option are presented in Figure 6.2.

Options	NPV capital costs: 2005-2010 (£millions)	NPV operating costs: 2005-2010 (£millions)	Change in NOx emissions: 2005-2010 (Tonnes)	Change in PM_{10} emissions: 2005-2010 (Tonnes)	CO emissions	HC emissions	Ground level ozone	Change in CO_2 emissions: 2005-2010 (kiloTonnes)	Noise	Congestion	Accident rate	Social cohesion	Quality of life	Distribution effects	Public/industry acceptability	Practicality
SCR with diesel particulate filter (10% uptake on heavy-duty vehicles) (LOW COST ESTIMATE)	£124.42	£79.83	-55,136	-1,537	2	1	3	0	0	0	0	0	1	-1	-1	-1
SCR with diesel particulate filter (10% uptake on heavy-duty vehicles) (HIGH COST ESTIMATE)	£311.05	£79.83	-55,136	-1,537	2	1	3	0	0	0	0	0	1	-1	-1	-1
EGR with diesel particulate filter (10% uptake on heavy-duty vehicles) (LOW COST ESTIMATE)	£108.87	£55.13	-38,171	-1,537	2	2	2	+219	0	0	0	0	1	-1	-1	-1
EGR with diesel particulate filter (10% uptake on heavy-duty vehicles) (HIGH COST ESTIMATE)	£311.05	£55.13	-38,171	-1,537	2	2	2	+219	0	0	0	0	1	-1	-1	-1
Euro 5 uptake in 2010 (Scenario C)	£52.92	£93.75	-10,925	-968	0	0	1	+301	0	0	0	0	1	0	-1	-1
Low emission passenger cars (10% of new car sales)	£384.83	-£500.34	-6,774	-268	2	2	1	-1735	1	0	0	0	1	0	1	1
Low emission passenger cars (40% of new car sales)	£1,188.10	-£1,538.94	-27,096	-1,074	3	3	3	-5358	1	0	0	0	1	0	1	-2
Hybrid-electric buses (Low CO_2 hybrid) (2% of bus fleet by 2010)	£45.20	-£10.08	-618	-15	2	2	1	-76	2	0	0	0	1	0	2	-1
Hybrid-electric buses (Low NOx / PM_{10} hybrid) (2% of bus fleet by 2010)	£45.20	£0.00	-1,240	-22	2	2	1	0	2	0	0	0	1	0	2	-1
Re-engining heavy duty vehicles with CNG/LNG engines (2% of Heavy Duty Vehicles by 2010)	£96.46	-£99.61	-7,330	-229	2	2	3	+1788	2	0	0	0	1	-3	-2	-3
Increased uptake of biofuels (5.00% of fuel sales)	£0.00	£1,659.60	0	0	0	0	0	-2120	0	0	0	0	1	0	0	-1
Increased uptake of biofuels (to meet 5.75% EU target level)	£0.00	£2,516.14	0	0	0	0	0	-3110	0	0	0	0	1	0	-1	-1
Water Diesel Emulsion (50% of buses and 2% of HGVs by 2010)	£0.00	£148.08	-13,943	-621	0	0	1	0	0	0	0	0	1	0	0	0
Water Diesel Emulsion (all buses and 10% of HGVs from 2006)	£0.00	£353.46	-36,579	-1,292	0	0	2	0	0	0	0	0	1	0	0	-1
Scrappage scheme (LOW COST ESTIMATE)	£0.00	£1,141.72	-76,666	-2,305	1	1	1	0	0	0	0	0	1	-1	1	-2
Scrappage scheme (HIGH COST ESTIMATE)	£0.00	£2,283.45	-76,666	-2,305	1	1	1	0	0	0	0	0	1	-1	1	-2
Low Emission Zones (LOW COST ESTIMATE)	£138.49	£49.95	-7,437	-1,570	1	1	1	0	0	0	0	0	1	-2	-1	-1
Low Emission Zones (HIGH COST ESTIMATE)	£288.07	£37.47	-7,437	-1,570	1	1	1	0	0	0	0	0	1	-2	-1	-1
Access control measures – restrictions on private cars in urban	£12.41	£0.00	-386	-30	1	1	1		1	3	2	-1	2	0	-2	-2
Lorry road user charging scheme			-952	-19	1	1	1	-253	0	0	0	0	0	0	1	-1
Public transport priority measures (bus lanes and guided busways) (LOW ESTIMATE)	£29.75	£0.00	-14	-4	1	1	1		0	1	0	1	2	2	0	-1
Public transport priority measures (bus lanes and guided busways) (HIGH ESTIMATE)	£45.15	£0.00	-211	-49	1	1	1		0	1	0	1	2	2	0	-1
Speed policy review (motorways) (LOW COST ESTIMATE)	£2.92	£0.00	-9,641	-88	1	1	1		2	-1	0	0	1	0	-3	-3
Speed policy review (motorways) (HIGH COST ESTIMATE)	£20.00	£0.00	-9,641	-88	1	1	1		2	-1	0	0	1	0	-3	-3
Car clubs / car sharing schemes	£4.07	£16.26	-205	-4	1	1	1	-116	0	1	0	1	2	1	-1	-1
MAX	£1,188.10	£2,516.14	-76,666	-2,305	3	3	3	-5,358	2	3	2	1	2	2	2	1
MIN	£0.00	-£1,538.94	0	0	0	0	0	1,788	0	-1	0	-1	0	-3	-3	-3
RANGE	£1,188.10	£4,055.09	-76,666	-2,305	3	3	3	-7,146	2	4	2	2	2	5	5	4

Figure 6.1: MCA performance matrix for options that could be implemented between 2005 and 2010

Normalisation	Capital costs	Operating costs	NOx emissions	PM_{10} emissions	CO emissions	HC emissions	Ground level ozor	CO_2 emissions	Noise	Congestion	Accident rate	Social cohesion	Quality of life	Distribution effect	Public acceptabili	Practicality
SCR with diesel particulate filter (10% uptake on heavy-duty vehicles) (LOW COST ESTIMATE)	89.5	60.1	71.9	66.7	67	33	100	25	0	25	0	50	50	40	40	50
SCR with diesel particulate filter (10% uptake on heavy-duty vehicles) (HIGH COST ESTIMATE)	73.8	60.1	71.9	66.7	67	33	100	25	0	25	0	50	50	40	40	50
EGR with diesel particulate filter (10% uptake on heavy-duty vehicles) (LOW COST ESTIMATE)	90.8	60.7	49.8	66.7	67	67	67	22	0	25	0	50	50	40	40	50
EGR with diesel particulate filter (10% uptake on heavy-duty vehicles) (HIGH COST ESTIMATE)	73.8	60.7	49.8	66.7	67	67	67	22	0	25	0	50	50	40	40	50
Euro 5 uptake in 2010 (Scenario C)	95.5	59.7	14.3	42.0	0	0	33	21	0	25	0	50	50	60	40	50
Low emission passenger cars (10% of new car sales)	67.6	74.4	8.8	11.6	67	67	33	49	50	25	0	50	50	60	80	100
Low emission passenger cars (40% of new car sales)	0.0	100.0	35.3	46.6	100	100	100	100	50	25	0	50	50	60	80	25
Hybrid-electric buses (Low CO_2 hybrid) (2% of bus fleet by 2010)	96.2	62.3	0.8	0.7	67	67	33	26	100	25	0	50	50	60	100	50
Hybrid-electric buses (Low NOx / PM_{10} hybrid) (2% of bus fleet by	96.2	62.0	1.6	0.9	67	67	33	25	100	25	0	50	50	60	100	50
Re-engining heavy duty vehicles with CNG/LNG engines (2% of Heavy Duty Vehicles by 2010)	91.9	64.5	9.6	9.9	67	67	100	0	100	25	0	50	50	0	20	0
Increased uptake of biofuels (5.00% of fuel sales)	100.0	21.1	0.0	0.0	0	0	0	55	0	25	0	50	50	60	60	50
Increased uptake of biofuels (to meet 5.75% EU target level)	100.0	0.0	0.0	0.0	0	0	0	69	0	25	0	50	50	60	40	50
Water Diesel Emulsion (50% of buses and 2% of HGVs by 2010)	100.0	58.4	18.2	27.0	0	0	33	25	0	25	0	50	50	60	60	75
Water Diesel Emulsion (all buses and 10% of HGVs from 2006)	100.0	53.3	47.7	56.1	0	0	67	25	0	25	0	50	50	60	60	50
Scrappage scheme (LOW COST ESTIMATE)	100.0	33.9	100.0	100.0	33	33	33	25	0	25	0	50	50	40	80	25
Scrappage scheme (HIGH COST ESTIMATE)	100.0	5.7	100.0	100.0	33	33	33	25	0	25	0	50	50	40	80	25
Low Emission Zones (LOW COST ESTIMATE)	88.3	60.8	9.7	68.1	33	33	33	25	0	25	0	50	50	20	40	50
Low Emission Zones (HIGH COST ESTIMATE)	75.8	61.1	9.7	68.1	33	33	33	25	0	25	0	50	50	20	40	50
Access control measures – restrictions on private cars in urban areas	99.0	62.0	0.5	1.3	33	33	33	25	50	100	100	0	100	60	20	25
Lorry road user charging scheme	100.0	62.0	1.2	0.8	33	33	33	29	0	25	0	50	0	60	80	50
Public transport priority measures (bus lanes and guided busways) (LOW ESTIMATE)	97.5	62.0	0.0	0.2	33	33	33	25	0	50	0	100	100	100	60	50
Public transport priority measures (bus lanes and guided busways) (HIGH ESTIMATE)	96.2	62.0	0.3	2.1	33	33	33	25	0	50	0	100	100	100	60	50
Speed policy review (motorways) (LOW COST ESTIMATE)	99.8	62.0	12.6	3.8	33	33	33	25	100	0	0	50	50	60	0	0
Speed policy review (motorways) (HIGH COST ESTIMATE)	98.3	62.0	12.6	3.8	33	33	33	25	100	0	0	50	50	60	0	0
Car clubs / car sharing schemes	99.7	61.6	0.3	0.2	33	33	33	27	0	50	0	100	100	80	40	50

Figure 6.2: Normalised MCA performance assessment scores for 2005-2010 options

It can be seen from the normalisation process that for some performance criteria, more than one option has the same normalised score attached. In particular, this can be seen quite often for some of the wider impacts where qualitative scores were used.

The next step in the MCA process is to apply weighting factors to each of the performance criteria and to the category themes in which the various performance criteria sit. The category themes are as follows:

Cost theme: consisting of capital costs and operating costs

Emissions theme: consisting of NOx, PM_{10}, CO, hydrocarbon, and CO_2 emissions. Ground level ozone is also included in this theme.

Traffic impacts theme: consisting of traffic noise, traffic congestion, and accident rate

Social impact theme: consisting of social cohesion, quality of life, and distributional effects

Feasibility theme: consisting of public/industry acceptability and practicality

The weighting factors need to take account of the fact that different performance criteria may be considered to be more or less important than one another. For example, reducing PM_{10} emissions could be viewed as being more important than reducing emissions of NOx. Alternatively, tackling congestion might be viewed as being more important than reducing traffic noise.

Within each individual category theme, the weighting factors applied to all of the performance criteria must total 100. So, for example, for the cost theme, there are two performance criteria (capital costs and operating costs), and the sum of the individual weighting factors applied to these must equal 100 (e.g. 50 and 50, or 60 and 40, etc). Example weighting factors for the emissions category theme are shown below in Figure 6.3. Once the individual performance criteria have been weighted, the same process is repeated for the category themes. In this case, there are five themes and again, the sum total of category theme weighting factors must equal 100.

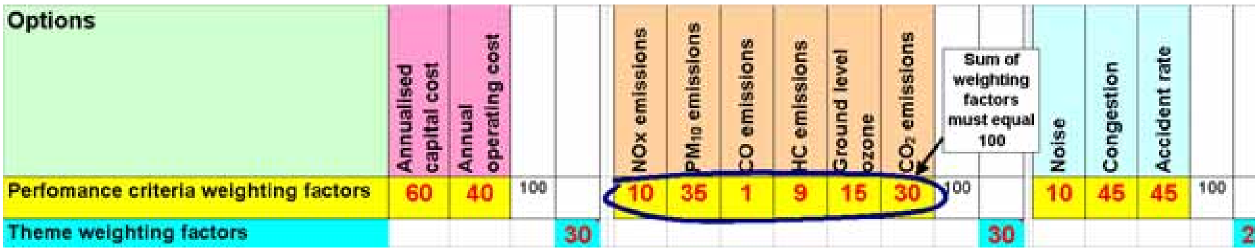

Figure 6.3: Example of making performance criteria weighting factors sum to 100

In Figure 6.4 overleaf, all of the weighting factors for both the performance criteria and category themes have been set to give a “flat” response – i.e. all performance criteria and themes are equally weighted. The “Total score” figures in the penultimate column of the matrix show the total weighted score for each option, taking into account the option’s performance against each of the different criteria. The total score can range from a minimum of 0 to a maximum of 100, with the most preferred option having the highest total score. The final column presents the rank position of each option with “1” indicating the most preferred, and subsequent rankings indicating decreasing levels of preference. With all criteria and themes equally weighted, it can be seen that the uptake of low CO_2 hybrid-electric buses is the most preferred option.

	Costs				Emissions								Traffic impacts					Social impacts					Feasibility					
Options	Annualised capital cost	Annual operating cost			NOx emissions	PM_{10} emissions	CO emissions	HC emissions	Ground level ozone	CO_2 emissions			Noise	Congestion	Accident rate			Social cohesion	Quality of life	Distribution effects			Public acceptability	Practicality			Total score	Rank
Perfomance criteria weighting factors	50	50	100		17	17	17	17	17	17	100		33	33	33	100		33	33	33	100		50	50	100		500	
Theme weighting factors				20								20					20					20				20	100	
SCR with diesel particulate filter (10% uptake on heavy-duty vehicles) (LOW COST ESTIMATE)	45	30	74.8	15.0	12	11	11	6	17	4	60.6	12.1	0	8	0	8	2	17	17	13	47	9.3	20	25	45	9.0	47.1	9
SCR with diesel particulate filter (10% uptake on heavy-duty vehicles) (HIGH COST ESTIMATE)	37	30	66.9	13.4	12	11	11	6	17	4	60.6	12.1	0	8	0	8	2	17	17	13	47	9.3	20	25	45	9.0	45.5	12
EGR with diesel particulate filter (10% uptake on heavy-duty vehicles) (LOW COST ESTIMATE)	45	30	76.8	15.2	8	11	11	11	11	4	56.4	11.3	0	8	0	8	2	17	17	13	47	9.3	20	25	45	9.0	46.4	10
EGR with diesel particulate filter (10% uptake on heavy-duty vehicles) (HIGH COST ESTIMATE)	37	30	67.3	13.5	8	11	11	11	11	4	56.4	11.3	0	8	0	8	2	17	17	13	47	9.3	20	25	45	9.0	44.7	15
Euro 5 uptake in 2010 (Scenario C)	48	30	77.8	15.5	2	7	0	0	6	3	18.4	3.7	0	8	0	8	2	17	17	20	53	10.7	20	25	45	9.0	40.5	19
Low emission passenger cars (10% of new car sales)	34	37	71.0	14.2	1	2	11	11	6	8	39.4	7.9	17	8	0	25	5	17	17	20	53	10.7	40	50	90	18.0	55.7	3
Low emission passenger cars (40% of new car sales)	0	50	50.0	10.0	6	8	17	17	17	17	80.3	16.1	17	8	0	25	5	17	17	20	53	10.7	40	13	53	10.5	52.2	6
Hybrid-electric buses (Low CO_2 hybrid) (2% of bus fleet by 2010)	48	31	79.2	15.8	0	0	11	11	6	4	32.4	6.5	33	8	0	42	8	17	17	20	53	10.7	50	25	75	15.0	56.3	1
Hybrid-electric buses (Low NOx / PM_{10} hybrid) (2% of bus fleet by 2010)	48	31	79.1	15.8	0	0	11	11	6	4	32.4	6.5	33	8	0	42	8	17	17	20	53	10.7	50	25	75	15.0	56.3	2
Re-engining heavy duty vehicles with CNG/LNG engines (2% of Heavy Duty Vehicles by 2010)	46	32	78.2	15.6	2	2	11	11	17	0	42.1	8.4	33	8	0	42	8	17	17	0	33	6.7	10	0	10	2.0	41.1	18
Increased uptake of biofuels (5.00% of fuel sales)	50	11	60.6	12.1	0	0	0	0	0	9	9.1	1.8	0	8	0	8	2	17	17	20	53	10.7	30	25	55	11.0	37.3	24
Increased uptake of biofuels (to meet 5.75% EU target level)	50	0	50.0	10.0	0	0	0	0	0	11	11.4	2.3	0	8	0	8	2	17	17	20	53	10.7	20	25	45	9.0	33.6	25
Water Diesel Emulsion (50% of buses and 2% of HGVs by 2010)	50	29	79.2	15.8	3	4	0	0	6	4	17.3	3.5	0	8	0	8	2	17	17	20	53	10.7	30	38	68	13.5	45.1	14
Water Diesel Emulsion (all buses and 10% of HGVs from 2006)	50	27	76.7	15.3	8	9	0	0	11	4	32.6	6.5	0	8	0	8	2	17	17	20	53	10.7	30	25	55	11.0	45.2	13
Scrappage scheme (LOW COST ESTIMATE)	50	17	66.9	13.4	17	17	6	6	6	4	54.2	10.8	0	8	0	8	2	17	17	13	47	9.3	40	13	53	10.5	45.7	11
Scrappage scheme (HIGH COST ESTIMATE)	50	3	52.9	10.6	17	17	6	6	6	4	54.2	10.8	0	8	0	8	2	17	17	13	47	9.3	40	13	53	10.5	42.9	16
Low Emission Zones (LOW COST ESTIMATE)	44	30	74.6	14.9	2	11	6	6	6	4	33.8	6.8	0	8	0	8	2	17	17	7	40	8.0	20	25	45	9.0	40.3	20
Low Emission Zones (HIGH COST ESTIMATE)	38	31	68.4	13.7	2	11	6	6	6	4	33.8	6.8	0	8	0	8	2	17	17	7	40	8.0	20	25	45	9.0	39.1	21
Access control measures – restrictions on private cars in urban areas	49	31	80.5	16.1	0	0	6	6	6	4	21.1	4.2	17	33	33	83	17	0	33	20	53	10.7	10	13	23	4.5	52.2	7
Lorry road user charging scheme	50	31	81.0	16.2	0	0	6	6	6	5	21.8	4.4	0	8	0	8	2	17	0	20	37	7.3	40	25	65	13.0	42.6	17
Public transport priority measures (bus lanes and guided busways) (LOW ESTIMATE)	49	31	79.8	16.0	0	0	6	6	6	4	20.9	4.2	0	17	0	17	3	33	33	33	100	20.0	30	25	55	11.0	54.5	4
Public transport priority measures (bus lanes and guided busways) (HIGH ESTIMATE)	48	31	79.1	15.8	0	0	6	6	6	4	21.2	4.2	0	17	0	17	3	33	33	33	100	20.0	30	25	55	11.0	54.4	5
Speed policy review (motorways) (LOW COST ESTIMATE)	50	31	80.9	16.2	2	1	6	6	6	4	23.6	4.7	33	0	0	33	7	17	17	20	53	10.7	0	0	0	0.0	38.2	22
Speed policy review (motorways) (HIGH COST ESTIMATE)	49	31	80.2	16.0	2	1	6	6	6	4	23.6	4.7	33	0	0	33	7	17	17	20	53	10.7	0	0	0	0.0	38.1	23
Car clubs / car sharing schemes	50	31	80.7	16.1	0	0	6	6	6	4	21.2	4.2	0	17	0	17	3	33	33	27	93	18.7	20	25	45	9.0	51.4	8

Figure 6.4: Ranking of options for the 2005-2010 time period with equal weighting factors applied to all category themes and performance criteria

In order to develop weighting factors for the performance criteria and category themes, a number of policy experts from government departments and other governmental organisations were consulted to obtain their personal views. The consultation was carried out as part of a workshop to discuss the different options for reducing emissions. The results of this consultation were used to adjust the weighting factors used and examine what influence this adjustment had on the total scores attached to each option and the overall ranking of options. A full MCA would traditionally have used consultation with expert groups from the full range of industry stakeholders in order to identify suitable weighting factors. However, within the resources available for this study, it was not possible to carry out such a complete approach as this would have entailed holding multiple workshops, and therefore it was decided that the consultation would be restricted to governmental policy experts. It should be noted that the weighting factors provided do not necessarily provide the individual Departments' views on how the different criteria should be weighted; they should be treated as the views of informed individuals or groups of individuals. Five separate MCA runs were carried out using five different sets of weighting factors, as supplied by the different groups of stakeholders. The different sets of weighting factors have been labelled from A1 to A5 and are presented below in Table 6.1 and Table 6.2.

Table 6.1: Performance criteria weighting factors used for each MCA run

Performance criteria	**Weighting factor used for each MCA run**				
	A1	**A2**	**A3**	**A4**	**A5**
Capital costs	60	50	60	60	60
Operating costs	40	50	40	40	40
NOx emissions	10	20	20	29	17
PM_{10} emissions	35	20	20	29	32
Carbon monoxide emissions	1	10	0	1	4
Hydrocarbon emissions	9	10	5	2	6
Ground level ozone	15	10	5	10	14
CO_2 emissions	30	30	50	29	27
Noise	10	30	20	80	25
Congestion	45	30	40	10	35
Accident rate	45	40	40	10	40
Social cohesion	10	30	33.3	5	30
Quality of life	50	40	33.3	15	40
Distribution effects	40	30	33.3	80	30
Public/industry acceptability	40	50	50	60	40
Practicality	60	50	50	40	60

Table 6.2 Category theme weighting factors used for each MCA run

Category theme	Weighting factor used for each MCA run				
	A1	A2	A3	A4	A5
Costs	30	28	35	20	30
Emissions	30	28	35	45	30
Traffic impacts	20	8	10	5	15
Social impacts	10	8	5	5	10
Feasibility	10	28	15	25	15

6.1.1 Summary of MCA runs

Each run of the analysis produced a different rank order for the various scenario options. The following tables (Table 6.3 to Table 6.7) provide a summary of the results from each MCA run, with the options displayed in descending order of preference. The detailed results from each run of the MCA can be found in Appendix 1.

Table 6.3: Rank ordering of options from MCA run A1

Scenario options	Total score	Rank
Access control measures – restrictions on private cars in urban areas	58.9	1
Scrappage scheme (LOW COST ESTIMATE)	51.9	2
SCR with diesel particulate filter (10% uptake on heavy-duty vehicles) (LOW COST ESTIMATE)	51.8	3
EGR with diesel particulate filter (10% uptake on heavy-duty vehicles) (LOW COST ESTIMATE)	50.6	4
Water Diesel Emulsion (all buses and 10% of HGVs from 2006)	50.0	5
Public transport priority measures (bus lanes and guided busways) (LOW ESTIMATE)	49.7	6
Public transport priority measures (bus lanes and guided busways) (HIGH ESTIMATE)	49.6	7
SCR with diesel particulate filter (10% uptake on heavy-duty vehicles) (HIGH COST ESTIMATE)	49.0	8
Car clubs / car sharing schemes	48.6	9
Scrappage scheme (HIGH COST ESTIMATE)	48.5	10
Low emission passenger cars (10% of new car sales)	48.4	11
Low emission passenger cars (40% of new car sales)	47.8	12
EGR with diesel particulate filter (10% uptake on heavy-duty vehicles) (HIGH COST ESTIMATE)	47.5	13
Hybrid-electric buses (Low CO_2 hybrid) (2% of bus fleet by 2010)	47.4	14
Hybrid-electric buses (Low NOx / PM_{10} hybrid) (2% of bus fleet by 2010)	47.3	15
Water Diesel Emulsion (50% of buses and 2% of HGVs by 2010)	46.7	16
Low Emission Zones (LOW COST ESTIMATE)	46.0	17
Euro 5 uptake in 2010 (Scenario C)	44.8	18
Low Emission Zones (HIGH COST ESTIMATE)	43.8	19
Lorry road user charging scheme	42.0	20
Re-engining heavy duty vehicles with CNG/LNG engines (2% of Heavy Duty Vehicles by 2010)	40.2	21
Increased uptake of biofuels (5.00% of fuel sales)	38.5	22
Speed policy review (motorways) (LOW COST ESTIMATE)	38.3	23
Speed policy review (motorways) (HIGH COST ESTIMATE)	38.1	24
Increased uptake of biofuels (to meet 5.75% EU target level)	36.4	25

Table 6.4: Rank ordering of options from MCA run A2

Scenario options	Total score	Rank
SCR with diesel particulate filter (10% uptake on heavy-duty vehicles) (LOW COST ESTIMATE)	61.1	1
EGR with diesel particulate filter (10% uptake on heavy-duty vehicles) (LOW COST ESTIMATE)	57.4	2
Hybrid-electric buses (Low NOx / PM_{10} hybrid) (2% of bus fleet by 2010)	57.3	3
Low emission passenger cars (40% of new car sales)	56.1	4
Scrappage scheme (LOW COST ESTIMATE)	53.9	5
Low emission passenger cars (10% of new car sales)	53.4	6
Hybrid-electric buses (Low CO_2 hybrid) (2% of bus fleet by 2010)	52.1	7
Public transport priority measures (bus lanes and guided busways) (LOW ESTIMATE)	51.8	8
Public transport priority measures (bus lanes and guided busways) (HIGH ESTIMATE)	51.8	9
Water Diesel Emulsion (all buses and 10% of HGVs from 2006)	51.5	10
Water Diesel Emulsion (50% of buses and 2% of HGVs by 2010)	51.5	11
SCR with diesel particulate filter (10% uptake on heavy-duty vehicles) (HIGH COST ESTIMATE)	51.2	12
Scrappage scheme (HIGH COST ESTIMATE)	50.0	13
EGR with diesel particulate filter (10% uptake on heavy-duty vehicles) (HIGH COST ESTIMATE)	49.8	14
Lorry road user charging scheme	49.4	15
Car clubs / car sharing schemes	49.0	16
Low Emission Zones (LOW COST ESTIMATE)	46.6	17
Access control measures – restrictions on private cars in urban areas	45.3	18
Euro 5 uptake in 2010 (Scenario C)	45.0	19
Low Emission Zones (HIGH COST ESTIMATE)	44.9	20
Increased uptake of biofuels (5.00% of fuel sales)	41.8	21
Re-engining heavy duty vehicles with CNG/LNG engines (2% of Heavy Duty Vehicles by 2010)	38.1	22
Increased uptake of biofuels (to meet 5.75% EU target level)	37.2	23
Speed policy review (motorways) (LOW COST ESTIMATE)	35.1	24
Speed policy review (motorways) (HIGH COST ESTIMATE)	34.9	25

Table 6.5: Rank ordering of options from MCA run A3

Scenario options	Total score	Rank
Scrappage scheme (LOW COST ESTIMATE)	56.5	1
SCR with diesel particulate filter (10% uptake on heavy-duty vehicles) (LOW COST ESTIMATE)	54.6	2
Low emission passenger cars (10% of new car sales)	53.7	3
Low emission passenger cars (40% of new car sales)	53.3	4
Water Diesel Emulsion (all buses and 10% of HGVs from 2006)	53.2	5
Scrappage scheme (HIGH COST ESTIMATE)	52.6	6
EGR with diesel particulate filter (10% uptake on heavy-duty vehicles) (LOW COST ESTIMATE)	52.3	7
Hybrid-electric buses (Low NOx / PM_{10} hybrid) (2% of bus fleet by 2010)	52.1	8
Hybrid-electric buses (Low CO_2 hybrid) (2% of bus fleet by 2010)	52.0	9
Water Diesel Emulsion (50% of buses and 2% of HGVs by 2010)	51.1	10
SCR with diesel particulate filter (10% uptake on heavy-duty vehicles) (HIGH COST ESTIMATE)	50.4	11
Access control measures – restrictions on private cars in urban areas	50.2	12
Public transport priority measures (bus lanes and guided busways) (LOW ESTIMATE)	50.0	13
Public transport priority measures (bus lanes and guided busways) (HIGH ESTIMATE)	49.9	14
Car clubs / car sharing schemes	48.8	15
Lorry road user charging scheme	48.6	16
EGR with diesel particulate filter (10% uptake on heavy-duty vehicles) (HIGH COST ESTIMATE)	48.4	17
Low Emission Zones (LOW COST ESTIMATE)	47.8	18
Euro 5 uptake in 2010 (Scenario C)	47.0	19
Increased uptake of biofuels (5.00% of fuel sales)	45.4	20
Low Emission Zones (HIGH COST ESTIMATE)	45.2	21
Increased uptake of biofuels (to meet 5.75% EU target level)	43.4	22
Speed policy review (motorways) (LOW COST ESTIMATE)	41.0	23
Speed policy review (motorways) (HIGH COST ESTIMATE)	40.7	24
Re-engining heavy duty vehicles with CNG/LNG engines (2% of Heavy Duty Vehicles by 2010)	38.8	25

Table 6.6: Rank ordering of options from MCA run A4

Scenario options	Total score	Rank
Scrappage scheme (LOW COST ESTIMATE)	62.8	1
Scrappage scheme (HIGH COST ESTIMATE)	60.5	2
Low emission passenger cars (40% of new car sales)	57.1	3
Low emission passenger cars (10% of new car sales)	55.2	4
SCR with diesel particulate filter (10% uptake on heavy-duty vehicles) (HIGH COST ESTIMATE)	53.3	5
Water Diesel Emulsion (all buses and 10% of HGVs from 2006)	53.1	6
SCR with diesel particulate filter (10% uptake on heavy-duty vehicles) (LOW COST ESTIMATE)	52.6	7
Hybrid-electric buses (Low CO_2 hybrid) (2% of bus fleet by 2010)	50.9	8
EGR with diesel particulate filter (10% uptake on heavy-duty vehicles) (LOW COST ESTIMATE)	49.5	9
Hybrid-electric buses (Low NOx / PM_{10} hybrid) (2% of bus fleet by 2010)	49.5	10
EGR with diesel particulate filter (10% uptake on heavy-duty vehicles) (HIGH COST ESTIMATE)	48.9	11
Water Diesel Emulsion (50% of buses and 2% of HGVs by 2010)	46.9	12
Low Emission Zones (LOW COST ESTIMATE)	43.3	13
Lorry road user charging scheme	42.6	14
Euro 5 uptake in 2010 (Scenario C)	41.8	15
Low Emission Zones (HIGH COST ESTIMATE)	41.8	16
Public transport priority measures (bus lanes and guided busways) (HIGH ESTIMATE)	41.3	17
Public transport priority measures (bus lanes and guided busways) (LOW ESTIMATE)	41.2	18
Increased uptake of biofuels (5.00% of fuel sales)	37.9	19
Car clubs / car sharing schemes	37.8	20
Increased uptake of biofuels (to meet 5.75% EU target level)	35.0	21
Access control measures – restrictions on private cars in urban areas	33.9	22
Re-engining heavy duty vehicles with CNG/LNG engines (2% of Heavy Duty Vehicles by 2010)	31.8	23
Speed policy review (motorways) (LOW COST ESTIMATE)	31.2	24
Speed policy review (motorways) (HIGH COST ESTIMATE)	31.0	25

Table 6.7: Rank ordering of options from MCA run A5

Scenario options	Total score	Rank
Scrappage scheme (LOW COST ESTIMATE)	54.3	1
Low emission passenger cars (10% of new car sales)	53.9	2
SCR with diesel particulate filter (10% uptake on heavy-duty vehicles) (LOW COST ESTIMATE)	52.3	3
Access control measures – restrictions on private cars in urban areas	52.2	4
Hybrid-electric buses (Low CO_2 hybrid) (2% of bus fleet by 2010)	52.1	5
Water Diesel Emulsion (all buses and 10% of HGVs from 2006)	51.8	6
EGR with diesel particulate filter (10% uptake on heavy-duty vehicles) (LOW COST ESTIMATE)	51.3	7
Hybrid-electric buses (Low NOx / PM_{10} hybrid) (2% of bus fleet by 2010)	51.2	8
SCR with diesel particulate filter (10% uptake on heavy-duty vehicles) (HIGH COST ESTIMATE)	51.1	9
Scrappage scheme (HIGH COST ESTIMATE)	50.9	10
Public transport priority measures (bus lanes and guided busways) (LOW ESTIMATE)	50.2	11
Public transport priority measures (bus lanes and guided busways) (HIGH ESTIMATE)	50.1	12
Low emission passenger cars (40% of new car sales)	49.1	13
EGR with diesel particulate filter (10% uptake on heavy-duty vehicles) (HIGH COST ESTIMATE)	49.0	14
Water Diesel Emulsion (50% of buses and 2% of HGVs by 2010)	48.9	15
Car clubs / car sharing schemes	48.8	16
Low Emission Zones (LOW COST ESTIMATE)	47.0	17
Euro 5 uptake in 2010 (Scenario C)	45.7	18
Low Emission Zones (HIGH COST ESTIMATE)	44.7	19
Lorry road user charging scheme	44.2	20
Re-engining heavy duty vehicles with CNG/LNG engines (2% of Heavy Duty Vehicles by 2010)	41.7	21
Speed policy review (motorways) (LOW COST ESTIMATE)	39.9	22
Increased uptake of biofuels (5.00% of fuel sales)	39.7	23
Speed policy review (motorways) (HIGH COST ESTIMATE)	39.6	24
Increased uptake of biofuels (to meet 5.75% EU target level)	37.1	25

6.1.2 Summary of analysis runs and identification of most preferred options

As can be seen from the above tables, each analysis run provides a different rank ordering of options. The final step of the analysis was to identify an overall ranking for the options based on the results from each MCA run. This has been achieved by averaging the total scores for each option for all MCA runs. The results of this process are presented Table 6.8. As can be seen from the Table, the most preferred options are the scrappage scheme, increased uptake of low emission passenger cars, and retrofit SCR for heavy-duty vehicles. The least preferred options are reduced speed limits for motorways close to urban areas, increased uptake of biofuels, and re-engining heavy duty vehicles with CNG engines.

Table 6.8: Final ranking of options for 2005-2010 based on average total scores

Scenario options	Total score from each MCA run					Average total score	Rank
	A1	A2	A3	A4	A5		
Scrappage scheme (LOW COST ESTIMATE)	51.9	53.9	56.5	62.8	54.3	55.9	1
Low emission passenger cars (10% of new car sales)	48.4	61.1	54.6	52.6	52.3	53.8	2
SCR with diesel particulate filter (10% uptake on heavy-duty vehicles) (LOW COST ESTIMATE)	51.8	53.4	53.7	55.2	53.9	53.6	3
Low emission passenger cars (40% of new car sales)	47.8	56.1	53.3	57.1	49.1	52.7	4
Scrappage scheme (HIGH COST ESTIMATE)	48.5	50.0	52.6	60.5	50.9	52.5	5
Water Diesel Emulsion (all buses and 10% of HGVs from 2006)	50.0	51.5	53.2	53.1	51.8	51.9	6
Hybrid-electric buses (Low CO_2 hybrid) (2% of bus fleet by 2010)	47.4	57.4	52.3	49.5	51.3	51.6	7
EGR with diesel particulate filter (10% uptake on heavy-duty vehicles) (LOW COST ESTIMATE)	50.6	52.1	52.0	50.9	52.1	51.5	8
Hybrid-electric buses (Low NOx / PM_{10} hybrid) (2% of bus fleet by 2010)	47.3	57.3	52.1	49.5	51.2	51.5	9
SCR with diesel particulate filter (10% uptake on heavy-duty vehicles) (HIGH COST ESTIMATE)	49.0	51.2	50.4	53.3	51.1	51.0	10
Water Diesel Emulsion (50% of buses and 2% of HGVs by 2010)	46.7	51.5	51.1	46.9	48.9	49.0	11
EGR with diesel particulate filter (10% uptake on heavy-duty vehicles) (HIGH COST ESTIMATE)	47.5	49.8	48.4	48.9	49.0	48.7	12
Public transport priority measures (bus lanes and guided busways) (LOW ESTIMATE)	49.7	51.8	50.0	41.2	50.2	48.6	13
Public transport priority measures (bus lanes and guided busways) (HIGH ESTIMATE)	49.6	51.8	49.9	41.3	50.1	48.5	14
Access control measures – restrictions on private cars in urban areas	58.9	45.3	50.2	33.9	52.2	48.1	15
Car clubs / car sharing schemes	48.6	49.0	48.8	37.8	48.8	46.6	16
Low Emission Zones (LOW COST ESTIMATE)	46.0	46.6	47.8	43.3	47.0	46.1	17
Lorry road user charging scheme	42.0	49.4	48.6	42.6	44.2	45.4	18
Euro 5 uptake in 2010 (Scenario C)	44.8	45.0	47.0	41.8	45.7	44.9	19
Low Emission Zones (HIGH COST ESTIMATE)	43.8	44.9	45.2	41.8	44.7	44.1	20
Increased uptake of biofuels (5.00% of fuel sales)	38.5	41.8	45.4	37.9	39.7	40.7	21
Re-engining heavy duty vehicles with CNG/LNG engines (2% of Heavy Duty Vehicles by 2010)	40.2	38.1	38.8	31.8	41.7	38.1	22
Increased uptake of biofuels (to meet 5.75% EU target level)	36.4	37.2	43.4	35.0	37.1	37.8	23
Speed policy review (motorways) (LOW COST ESTIMATE)	38.3	35.1	41.0	31.2	39.9	37.1	24
Speed policy review (motorways) (HIGH COST ESTIMATE)	38.1	34.9	40.7	31.0	39.6	36.9	25

6.2 Analysis of options for the 2011 to 2025 time period

A similar set of Multi-Criteria Analysis runs have been carried out for options that could be implemented between 2011 and 2025. First, the performance matrix was constructed using the qualitative data presented for each option in Chapter 4 (see Figure 6.5 overleaf). As before, the data in this matrix was normalised to give scores ranging from 0 (for the least preferred option) to 100 (for the most preferred option) against each of the performance criteria. Finally, the initial set of weighting factors were applied to the various category themes and performance criteria in order that all of the performance criteria are equally weighted (see Figure 6.6).

Assessment	Annualised capital cost	Annual operating cost	NOx emissions abatement	PM_{10} emissions abatement	CO emissions	HC emissions	Ground level ozone	CO_2 emissions	Noise	Congestion	Accident rate	Social cohesion	Quality of life	Distribution effects	Public/industry acceptability	Practicality
Battery-powered electric Vehicles	-2	0	2	2	2	2	2	2	3	0	0	0	1	0	-1	-1
H_2 fuel cell vehicles for Captive fleets	-3	-1	2	2	2	2	2	1	3	0	0	0	1	0	-3	-2
New diesel formulations	-1	1	0	2	0	0	0	1	0	0	0	0	1	0	3	3
Scrappage scheme for Euro 2, Euro 3 and Euro 4 vehicles	1	-2	1	1	1	1	1	0	0	0	0	0	1	-1	-1	-3
Road user charging (all Vehicles and all roads)	-3	-2	2	2	2	2	2	2	1	1	1	0	1	1	-2	-2
Extended Low Emissions Zones	-2	-2	3	3	3	3	2	1	0	0	0	0	1	-2	-3	-2
Freight distribution centres and intermodal freight transfer	-2	-1	1	1	1	1	1	1	1	1	0	0	1	0	-1	-1
Further integrated land use and transport planning	0	-1	1	1	1	1	1	1	0	1	0	1	2	0	1	-2
Dynamic route planning	-1	-1	1	1	1	1	1	0	0	1	0	0	1	0	1	1
Emissions Trading Scheme for Heavy-duty vehicles and taxis	0	-1	1	1	1	1	1	2	0	0	0	0	0	-3	-3	-2
Personal Carbon Accounts	0	-2	1	1	1	1	1	2	0	1	0	0	0	0	-3	-2

Figure 6.5: MCA performance matrix for options that could be implemented between 2011 and 2025

Options	Annualised capital cost	Annual operating cost			NOx emissions abatement	PM_{10} emissions abatement	CO emissions	HC emissions	Ground level ozone	CO_2 emissions			Noise	Congestion	Accident rate			Social cohesion	Quality of life	Distribution effects			Public/industry acceptability	Practicality			Total score	Rank
Perfomance criteria weighting factors	50	50	100		17	17	17	17	17	17	100		33	33	33	100		33	33	33	100		50	50	100		500	
Theme weighting factors				20								20					20					20				20	100	
Battery-powered electric Vehicles	15	27	42	8	15	11	1	3	15	35	80	16	30	0	0	30	6	0	17	25	42	8	13	20	33	7	45.3	3
H_2 fuel cell vehicles for Captive fleets	0	13	13	3	15	11	1	3	15	18	62	12	30	0	0	30	6	0	17	25	42	8	0	10	10	2	31.4	8
New diesel formulations	30	40	70	14	0	11	0	0	0	18	29	6	0	0	0	0	0	0	17	25	42	8	40	60	100	20	48.0	2
Scrappage scheme for Euro 2, Euro 3 and Euro 4 vehicles	60	0	60	12	7	0	1	1	8	0	17	3	0	0	0	0	0	0	17	17	33	7	13	0	13	3	24.7	10
Road user charging (all Vehicles and all roads)	0	0	0	0	15	11	1	3	15	35	80	16	10	35	35	80	16	0	17	33	50	10	7	10	17	3	45.3	4
Extended Low Emissions Zones	15	0	15	3	22	22	2	4	15	18	83	17	0	0	0	0	0	0	17	8	25	5	0	10	10	2	26.5	9
Freight distribution centres and intermodal freight transfer	15	13	28	6	7	0	1	1	8	18	34	7	10	35	0	45	9	0	17	25	42	8	13	20	33	7	36.5	6
Further integrated land use and transport planning	45	13	58	12	7	0	1	1	8	18	34	7	0	35	0	35	7	33	33	25	92	18	27	10	37	7	51.2	1
Dynamic route planning	30	13	43	9	7	0	1	1	8	0	17	3	0	35	0	35	7	0	17	25	42	8	27	40	67	13	40.7	5
Emissions Trading Scheme for Heavy-duty vehicles and taxis	45	13	58	12	7	0	1	1	8	35	52	10	0	0	0	0	0	0	0	0	0	0	0	10	10	2	24.0	11
Personal Carbon Accounts	45	0	45	9	7	0	1	1	8	35	52	10	0	35	0	35	7	0	0	25	25	5	0	10	10	2	33.4	7

Figure 6.6: Ranking of options for the 2011-2025 time period with equal weighting factors applied to all category themes and performance criteria

Using the weighting factors shown in Figure 6.6 to initially provide equal weightings for all the performance criteria, the Multi-Criteria Analysis run identifies the national road-user charging scheme as the most preferred option. As with the 2005-2010 time period, it was then necessary to apply a series of different variants of weighting factors and carry out a number of analysis runs to identify the most preferred options for further investigation. Some of the stakeholders provided different sets of weighting factors for each of the time periods. This allows the possibility of increasing or decreasing the importance of particular criteria over time (e.g. it could be argued that abatement of CO_2 emissions will become more important in future years). The different sets of weighting factors used for options in the 2011-2025 time periods have been labelled from B1 to B5, and details of these factors are presented below in Table 6.9 and Table 6.10.

Table 6.9: Performance criteria weighting factors used for each MCA run

Performance criteria	**Weighting factor used for each MCA run**				
	B1	**B2**	**B3**	**B4**	**B5**
Capital costs	50	50	60	60	60
Operating costs	50	50	40	40	40
NOx emissions	8	20	20	24	22
PM_{10} emissions	35	20	20	31	22
Carbon monoxide emissions	0	10	0	1	2
Hydrocarbon emissions	5	10	5	3	4
Ground level ozone	12	10	5	10	15
CO_2 emissions	40	30	50	31	35
Noise	10	30	20	80	30
Congestion	45	30	40	10	35
Accident rate	45	40	40	10	35
Social cohesion	10	30	33.33	5	33
Quality of life	50	40	33.33	15	33
Distribution effects	40	30	33.33	80	33
Public/industry acceptability	40	50	50	60	40
Practicality	60	50	50	40	60

Table 6.10: Category theme weighting factors used for each MCA run

Category theme	**Weighting factor used for each MCA run**				
	B1	**B2**	**B3**	**B4**	**B5**
Costs	25	28	35	20	35
Emissions	35	28	35	45	35
Traffic impacts	20	8	10	5	12
Social impacts	10	8	5	5	5
Feasibility	10	28	15	25	13

6.2.1 Summary of MCA runs

The results from each analysis run are presented in the following tables (Table 6.11 to Table 6.15). The options have been ranked according to the total score achieved in each run (in descending order of preference).

Table 6.11: Rank ordering of options from MCA run B1

Scenario options	Total score	Rank
Battery-powered electric Vehicles	52.6	1
Road user charging (all Vehicles and all roads)	48.3	2
Further integrated land use and transport planning	47.3	3
New diesel formulations	42.5	4
Personal Carbon Accounts	40.7	5
H_2 fuel cell vehicles for Captive fleets	37.1	6
Freight distribution centres and intermodal freight transfer	36.4	7
Extended Low Emissions Zones	36.4	8
Dynamic route planning	35.4	9
Emissions Trading Scheme for Heavy-duty vehicles and taxis	33.7	10
Scrappage scheme for Euro 2, Euro 3 and Euro 4 vehicles	26.1	11

Table 6.12: Rank ordering of options from MCA run B2

Scenario options	Total score	Rank
New diesel formulations	59.6	1
Battery-powered electric Vehicles	49.7	2
Further integrated land use and transport planning	47.0	3
Dynamic route planning	42.3	4
Road user charging (all Vehicles and all roads)	35.6	5
Personal Carbon Accounts	35.4	6
Freight distribution centres and intermodal freight transfer	34.5	7
Emissions Trading Scheme for Heavy-duty vehicles and taxis	33.6	8
Extended Low Emissions Zones	32.3	9
H_2 fuel cell vehicles for Captive fleets	30.3	10
Scrappage scheme for Euro 2, Euro 3 and Euro 4 vehicles	28.4	11

Table 6.13: Rank ordering of options from MCA run B3

Scenario options	Total score	Rank
Battery-powered electric Vehicles	53.0	1
New diesel formulations	52.0	2
Further integrated land use and transport planning	46.4	3
Personal Carbon Accounts	40.6	4
Emissions Trading Scheme for Heavy-duty vehicles and taxis	40.1	5
Road user charging (all Vehicles and all roads)	39.8	6
Dynamic route planning	37.1	7
Extended Low Emissions Zones	37.0	8
Freight distribution centres and intermodal freight transfer	33.9	9
H_2 fuel cell vehicles for Captive fleets	33.4	10
Scrappage scheme for Euro 2, Euro 3 and Euro 4 vehicles	30.8	11

Table 6.14: Rank ordering of options from MCA run B4

Scenario options	Total score	Rank
Battery-powered electric Vehicles	56.5	1
New diesel formulations	54.3	2
Road user charging (all Vehicles and all roads)	45.4	3
Extended Low Emissions Zones	44.0	4
Further integrated land use and transport planning	43.0	5
Personal Carbon Accounts	38.2	6
Emissions Trading Scheme for Heavy-duty vehicles and taxis	37.5	7
Dynamic route planning	37.2	8
H_2 fuel cell vehicles for Captive fleets	37.1	9
Freight distribution centres and intermodal freight transfer	34.2	10
Scrappage scheme for Euro 2, Euro 3 and Euro 4 vehicles	24.9	11

Table 6.15: Rank ordering of options from MCA run B5

Scenario options	Total score	Rank
Battery-powered electric Vehicles	52.9	1
New diesel formulations	50.0	2
Further integrated land use and transport planning	46.4	3
Road user charging (all Vehicles and all roads)	41.0	5
Personal Carbon Accounts	41.1	4
Emissions Trading Scheme for Heavy-duty vehicles and taxis	39.9	6
Extended Low Emissions Zones	36.8	7
Dynamic route planning	36.4	8
Freight distribution centres and intermodal freight transfer	34.2	9
H_2 fuel cell vehicles for Captive fleets	33.8	10
Scrappage scheme for Euro 2, Euro 3 and Euro 4 vehicles	30.6	11

6.2.2 Summary of analysis runs and identification of most preferred options

As with options for the 2005-2010 time period, the results from MCA runs B1 to B5 have been averaged so that an overall average total score could be applied to each scenario option, and consequently, a final ranking of options could be identified. The results of this process are presented below in Table 6.16.

Table 6.16: Final ranking of options for 2011-2025 based on average total scores

Scenario options	Total score from each MCA run					Average total score	Rank
	B1	B2	B3	B4	B5		
Battery-powered electric Vehicles	52.6	49.7	53.0	56.5	52.9	52.9	1
New diesel formulations	42.5	59.6	52.0	54.3	50.0	51.7	2
Further integrated land use and transport planning	47.3	47.0	46.4	43.0	46.4	46.0	3
Road user charging (all Vehicles and all roads)	48.3	35.6	39.8	45.4	41.0	42.0	4
Personal Carbon Accounts	40.7	35.4	40.6	38.2	41.1	39.2	5
Extended Low Emissions Zones	36.4	32.3	37.0	44.0	36.8	37.3	7
Dynamic route planning	35.4	42.3	37.1	37.2	36.4	37.7	6
Emissions Trading Scheme for Heavy-duty vehicles and taxis	33.7	33.6	40.1	37.5	39.9	37.0	8
Freight distribution centres and intermodal freight transfer	36.4	34.5	33.9	34.2	34.2	34.6	9
H_2 fuel cell vehicles for Captive fleets	37.1	30.3	33.4	37.1	33.8	34.4	10
Scrappage scheme for Euro 2, Euro 3 and Euro 4 vehicles	26.1	28.4	30.8	24.9	30.6	28.1	11

As can be seen from the Table, increased uptake of battery electric vehicles has been identified as the most preferred option, followed by new diesel formulations, and further integrated land use and transport planning. The least preferred options identified from the analysis runs are the scrappage scheme for Euro 2/3/4 vehicles, and hydrogen fuel cell vehicles for captive vehicle fleets.

6.3 Analysis of options for the 2025 to 2050 time period

In the same manner as for the other two time periods, the results of the assessment of scenario options for the 2025-2050 time period were assembled into a MCA performance matrix in order that analysis to identify the most preferred options could be carried out. The performance matrix for these options is presented overleaf.

Assessment	Annualised capital cost	Annual operating cost	NOx emissions abatement	PM_{10} emissions abatement	CO emissions	HC emissions	Ground level ozone	CO_2 emissions	Noise	Congestion	Accident rate	Social cohesion	Quality of life	Distribution effects	Public/industry acceptability	Practicality
Large-scale uptake of hydrogen fuel cell passenger cars	0	0	3	3	3	3	3	3	3	0	0	0	1	0	0	0
Automated Highways	-2	-2	1	1	1	1	1	1	0	2	1	0	2	0	-2	-3
Complete substitution of petrol and diesel by biofuels	-1	-1	0	0	0	0	0	2	0	0	0	0	1	0	0	1
Fast moving-walkways for short urban journeys	-3	-2	1	1	1	1	1	1	0	1	1	1	1	0	1	-3
Dedicated road freight systems	-3	-2	1	1	1	1	1	1	0	1	1	0	1	0	1	-3
Passenger cars with inter-modal functionality	-1	-1	1	1	1	1	1	1	0	2	1	0	1	0	-1	-3
Scrappage scheme for Petrol and Diesel vehicles	-1	-3	2	2	2	2	2	2	1	0	0	0	1	0	-1	-2
Fuel duty differential based on Life-cycle emissions	0	-1	2	2	2	2	2	2	1	0	0	0	1	-2	-2	2
MAX	0	0	3	3	3	3	3	3	3	2	1	1	2	0	1	2
MIN	-3	-3	0	0	0	0	0	1	0	0	0	0	1	-2	-2	-3
RANGE	3	3	3	3	3	3	3	2	3	2	1	1	1	2	3	5

Figure 6.7: MCA performance matrix for options that could be implemented between 2025 and 2050

The scores in the performance matrix were then normalised to a scale ranging from 0 to 100, and the initial set of weighting factors were applied to various category themes and performance criteria in order that all of the performance criteria were equally weighted. The normalised data with the equally distributed weighting factors are presented overleaf in Figure 6.8.

Options	Annualised capital cost	Annual operating cost			NOx emissions abatement	PM_{10} emissions abatement	CO emissions	HC emissions	Ground level ozone	CO_2 emissions			Noise	Congestion	Accident rate			Social cohesion	Quality of life	Distribution effects			Public/industry acceptability	Practicality			Total score	Rank
Perfomance criteria weighting factors	50	50	100		17	17	17	17	17	17	100		33	33	33	100		33	33	33	100		50	50	100		500	
Theme weighting factors				20								20					20					20				20	100	
Large-scale uptake of hydrogen fuel cell passenger cars	50	50	100	20	17	17	17	17	17	17	100	20	33	0	0	33	7	0	0	33	33	7	33	30	63	13	66.0	1
Automated Highways	17	17	33	7	6	6	6	6	6	0	28	6	0	33	33	67	13	0	33	33	67	13	0	0	0	0	38.9	5
Complete substitution of petrol and diesel by biofuels	33	33	67	13	0	0	0	0	0	8	8	2	0	0	0	0	0	0	0	33	33	7	33	40	73	15	36.3	6
Fast moving-walkways for short urban journeys	0	17	17	3	6	6	6	6	6	0	28	6	0	17	33	50	10	33	0	33	67	13	50	0	50	10	42.2	3
Dedicated road freight systems	0	17	17	3	6	6	6	6	6	0	28	6	0	17	33	50	10	0	0	33	33	7	50	0	50	10	35.6	7
Passenger cars with inter-modal functionality	33	33	67	13	6	6	6	6	6	0	28	6	0	33	33	67	13	0	0	33	33	7	17	0	17	3	42.2	2
Scrappage scheme for Petrol and Diesel vehicles	33	0	33	7	11	11	11	11	11	8	64	13	11	0	0	11	2	0	0	33	33	7	17	10	27	5	33.7	8
Fuel duty differential based on Life-cycle emissions	50	33	83	17	11	11	11	11	11	8	64	13	11	0	0	11	2	0	0	0	0	0	0	50	50	10	41.7	4

Figure 6.8: Ranking of options for the 2025-2050 time period with equal weighting factors applied to all category themes and performance criteria

As with the previous rounds of analysis carried out for the earlier time periods, five different sets of weighting factors were used (labelled from C1 to C5), as provided by Government stakeholders. These weighting factors are presented below in Table 6.17 and Table 6.18.

Table 6.17: Performance criteria weighting factors used for each MCA run

Performance criteria	**Weighting factor used for each MCA run**				
	C1	**C2**	**C3**	**C4**	**C5**
Capital costs	40	50	60	60	40
Operating costs	60	50	40	40	60
					0
NOx emissions	9	20	20	16	12
PM_{10} emissions	30	20	20	35	35
Carbon monoxide emissions	0	10	0	1	2
Hydrocarbon emissions	1	10	5	3	5
Ground level ozone	10	10	5	10	11
CO_2 emissions	50	30	50	35	35
					0
Noise	10	30	20	80	30
Congestion	45	30	40	10	35
Accident rate	45	40	40	10	35
Social cohesion	10	30	33.3	5	33.3
Quality of life	50	40	33.3	15	33.3
Distribution effects	40	30	33.3	80	33.3
	0				
Public/industry acceptability	50	50	50	60	60
Practicality	50	50	50	40	40

Table 6.18: Category theme weighting factors used for each MCA run

Category theme	**Weighting factor used for each MCA run**				
	C1	**C2**	**C3**	**C4**	**C5**
Costs	20	28	35	20	30
Emissions	35	28	35	45	35
Traffic impacts	20	8	10	5	10
Social impacts	15	8	5	5	10
Feasibility	10	28	15	25	15

6.3.1 Summary of MCA runs

The results of MCA runs C1 to C5 are presented below in Table 6.19 to Table 6.23.

Table 6.19: Rank ordering of options from MCA run C1

Scenario options	Total score	Rank
Large-scale uptake of hydrogen fuel cell passenger cars	73.0	1
Fuel duty differential based on Life-cycle emissions	46.2	2
Passenger cars with inter-modal functionality	43.1	3
Automated Highways	39.7	4
Scrappage scheme for Petrol and Diesel vehicles	38.9	5
Fast moving-walkways for short urban journeys	38.1	6
Dedicated road freight systems	33.1	7
Complete substitution of petrol and diesel by biofuels	28.6	8

Table 6.20: Rank ordering of options from MCA run C2

Scenario options	Total score	Rank
Large-scale uptake of hydrogen fuel cell passenger cars	79.1	1
Fuel duty differential based on Life-cycle emissions	56.1	2
Complete substitution of petrol and diesel by biofuels	44.2	3
Passenger cars with inter-modal functionality	39.1	4
Scrappage scheme for Petrol and Diesel vehicles	38.2	5
Fast moving-walkways for short urban journeys	35.8	6
Dedicated road freight systems	33.1	7
Automated Highways	27.8	8

Table 6.21: Rank ordering of options from MCA run C3

Scenario options	Total score	Rank
Large-scale uptake of hydrogen fuel cell passenger cars	84.5	1
Fuel duty differential based on Life-cycle emissions	60.1	2
Passenger cars with inter-modal functionality	43.9	3
Scrappage scheme for Petrol and Diesel vehicles	40.8	4
Complete substitution of petrol and diesel by biofuels	38.9	5
Fast moving-walkways for short urban journeys	31.4	6
Automated Highways	31.4	7
Dedicated road freight systems	29.7	8

Table 6.22: Rank ordering of options from MCA run C4

Scenario options	Total score	Rank
Large-scale uptake of hydrogen fuel cell passenger cars	84.2	1
Fuel duty differential based on Life-cycle emissions	58.5	2
Scrappage scheme for Petrol and Diesel vehicles	44.3	3
Complete substitution of petrol and diesel by biofuels	37.1	4
Passenger cars with inter-modal functionality	35.0	5
Fast moving-walkways for short urban journeys	34.2	6
Dedicated road freight systems	32.5	7
Automated Highways	25.8	8

Table 6.23: Rank ordering of options from MCA run C5

Scenario options	Total score	Rank
Large-scale uptake of hydrogen fuel cell passenger cars	81.2	1
Fuel duty differential based on Life-cycle emissions	56.0	2
Passenger cars with inter-modal functionality	42.2	3
Scrappage scheme for Petrol and Diesel vehicles	40.8	4
Complete substitution of petrol and diesel by biofuels	37.2	5
Fast moving-walkways for short urban journeys	33.9	6
Automated Highways	33.1	7
Dedicated road freight systems	30.6	8

6.3.2 Summary of analysis runs and identification of most preferred options

The results from the five analysis runs have been averaged to provide average total scores and a final rank ordering of scenario options for the 2025-2050 time period. The final rank ordering is presented below in Table 6.24.

Table 6.24: Final ranking of options for 2025-2050 based on average total scores

Scenario options	Total score from each MCA run					Average total score	Rank
	C1	C2	C3	C4	C5		
Large-scale uptake of hydrogen fuel cell passenger cars	73.0	79.1	84.5	84.2	81.2	80.4	1
Fuel duty differential based on life-cycle emissions	46.2	56.1	60.1	58.5	56.0	57.7	2
Scrappage scheme for Petrol and Diesel vehicles	38.9	38.2	40.8	44.3	40.8	41.0	3
Passenger cars with inter-modal functionality	43.1	39.1	43.9	35.0	42.2	40.1	4
Complete substitution of petrol and diesel by biofuels	28.6	44.2	38.9	37.1	37.2	37.2	5
Fast moving-walkways for short urban journeys	38.1	35.8	31.4	34.2	33.9	33.8	6
Dedicated road freight systems	33.1	33.1	29.7	32.5	30.6	31.5	7
Automated Highways	39.7	27.8	31.4	25.8	33.1	29.5	8

The results of the analysis runs indicate that large-scale uptake of hydrogen fuel cell cars is the most preferred option; for all five analysis runs, it obtained the highest overall score.

6.4 Discussion of MCA results and the influence of weighting factors

It is clear from the MCA runs carried out for the three time periods that the choice of weighting factors used for the different performance criteria and category themes plays a major part in the overall rank ordering of options. As discussed earlier, the weighting factors used in this study were proposed by governmental policy experts, and as might be expected, different individuals hold different views with regard to the levels of importance that should be applied to individual performance criteria. During the course of this study it was not possible to arrive at a single set of weighting factors which all the policy experts could agree on, hence the need for separate analysis runs using the different sets of weighting factors. By comparing the results from different analysis runs, it can be seen that in some cases, the differences in the weighting factors used has had a dramatic effect on the rank ordering of options. For example, for the 2005-2010 time period, the five sets of weighting factors led to three different options being ranked as the most preferred, as shown in Table 6.25.

Table 6.25: Variations in the rank ordering of options: most preferred options for the 2005-2010 time period

Scenario options	Rank order of options				
	A1	A2	A3	A4	A5
Scrappage scheme (LOW COST ESTIMATE)	2	5	1	1	1
Low emission passenger cars (10% of new car sales)	11	1	2	7	3
Access control measures – restrictions on private cars in urban areas	1	18	12	22	4

As can be seen from the table, analysis runs A3, A4, and A5 all result in the scrappage scheme for pre-Euro and Euro 1 passenger cars being selected as the highest ranked (most preferred) option, whilst run A1 ranks this option as the second most preferred and run A2 ranks it as fifth most preferred. The results of analysis run A2 put low emission passenger cars as the highest ranked option, whilst the other runs place this option between second and eleventh most preferred. An even greater variation in rank order position can be seen for the access control measures option; run A1 ranks this option as the most preferred, whilst run A4 positions it in 22nd place out of 25 options. However, whilst it is clear from these examples that the different MCA runs can in some instances provide very different rank orderings of options, it should be stressed that for the most part, the different sets of weighting factors provide a broad level of agreement with regard to the most preferred and least preferred options. For example, as can be seen in Table 6.25 the scrappage scheme has been selected as the most preferred option in three out of five analysis runs. Similarly, at the other end of the scale, the different analysis runs provide a broad level of agreement with regard to the least preferred options. In Table 6.26 below, it can be seen that the high cost estimate option for revised speed policies on urban motorways is ranked in 25th place by two of the analysis runs, and in 24th place by the remaining three runs. Similarly, the other options presented in the table are all ranked in 21st place or lower by each analysis run, again indicating a good level of consistency in the MCA result outputs.

Table 6.26: Variations in the rank ordering of options: least preferred options for the 2005-2010 time period

Scenario options	Rank order of options				
	A1	A2	A3	A4	A5
Re-engining heavy duty vehicles with CNG/LNG engines	21	22	25	23	21
Increased uptake of biofuels (to meet 5.75% EU target level)	25	23	22	21	25
Speed policy review (motorways) (LOW COST ESTIMATE)	23	24	23	24	22
Speed policy review (motorways) (HIGH COST ESTIMATE)	24	25	24	25	24

A similar situation can also be found if the results of the analysis runs for the 2011-2025 options are examined. In Table 6.27, some of the option rank ordering results from analysis runs B1 to B5 are presented; as can be seen from the Table, in four out of five analysis runs, battery-electric vehicles have been identified as the highest ranked option (in the remaining analysis run, this option was ranked second), whilst new diesel formulations were ranked in second place by three out of five analysis runs, and integrated land use/transport planning was ranked in third place in four out of five analysis runs. Similarly, Table 6.28 shows the rank ordering results for the least preferred options identified in the same five analysis runs. As can be seen, all five analysis runs place the scrappage scheme for Euro 2, 3, and 4 vehicles as the lowest ranked option, whilst three analysis runs position hydrogen fuel cells for captive vehicle fleets in tenth place out of eleven options.

Table 6.27: Variations in the rank ordering of options: most preferred options for the 2011-2025 time period

Scenario options	Rank order from each MCA run				
	B1	B2	B3	B4	B5
Battery-powered electric Vehicles	1	2	1	1	1
New diesel formulations	4	1	2	2	2
Further integrated land use and transport planning	3	3	3	5	3

Table 6.28: Variations in the rank ordering of options: least preferred options for the 2011-2025 time period

Scenario options	Rank order from each MCA run				
	B1	B2	B3	B4	B5
Freight distribution centres and intermodal freight transfer	8	7	9	10	9
H_2 fuel cell vehicles for Captive fleets	6	10	10	9	10
Scrappage scheme for Euro 2, Euro 3 and Euro 4 vehicles	11	11	11	11	11

Based on these observations, it can be seen that even though different sets of weighting factors have been used, the different MCA runs can be used to identify the least preferred and most preferred options in a relatively consistent fashion.

For this reason, the scores from the five analysis runs carried out for each time period have been averaged to provide a mean MCA score for each option and an overall rank ordering of options, thereby allowing the options to be prioritised for further study. In theory, a single set of agreed weighting factors would have been used for each time period; in practice it was not possible to develop single sets of weighting factors. Averaging the results of the MCA runs is a method that has been used to try to overcome this problem, and whilst not ideal, the methodology does allow the options to be ranked for further study, taking into account the proposed weighting factors supplied by the five different policy expert groups. It is clear from the examples provided in the foregoing tables that although the different sets of weighting factors influence the precise rank ordering of options, there is broad agreement across all analysis runs on the most preferred and least preferred options for a particular time period. The average MCA scores and overall rank ordering of options for each time period are presented in the results tables in Sections 6.1 to 6.3.

7 Cost Benefit Analysis of Options for the 2005-2010 time period

7.1 Overview

This section compares the different measures assessed for the 2005-2010 time period in terms of their pollutant and greenhouse gas emission benefits. The approach taken in this analysis has been to first rank the different options in terms of their NOx, PM_{10}, and CO_2 emissions abatement performance; further analysis has then been undertaken to assess the economic benefits associated with reductions in emissions associated with each option.

7.2 Ranking of options based on emissions abatement performance

Table 7.1 ranks the different options in terms of NOx and PM_{10} emissions abatement performance.

Table 7.1: Rank ordering of options with respect to NOx and PM_{10} emissions abatement performance

Rank	Option	Reduction in NOx emissions 2005-2010 (kiloTonnes)	Option	Reduction in PM_{10} emissions 2005-2010 (kiloTonnes)
1	Retrofit SCR + Diesel particulate filter for heavy duty vehicles	-55.14	Retrofit SCR + Diesel particulate filter for heavy duty vehicles	-1.537
2	Retrofit EGR + Diesel particulate filter for heavy duty vehicles	-38.17	Retrofit EGR + Diesel particulate filter for heavy duty vehicles	-1.537
3	Water Diesel Emulsion fuel (10% HGVs and 100% of buses from 2006)	-36.58	Water Diesel Emulsion fuel (10% HGVs and 100% of buses from 2006)	-1.292
4	Hybrid passenger cars (40% of new car sales)	-27.10	Euro V (Scenario C) (DfT)	-0.967
5	Water Diesel Emulsion fuel (2% HGVs and 10% buses in 2006, rising to 10% and 50% in 2010)	-13.94	Hybrid passenger cars (40% of new car sales)	-0.475
6	Euro V (Scenario C) (DfT)	-10.93	Scrappage scheme for pre-Euro and Euro 1 cars	-0.300
7	Scrappage scheme for pre-Euro and Euro 1 cars	-7.64	Low Emission Zones	-0.248
8	Retrofit CNG for heavy duty vehicles	-7.33	Water Diesel Emulsion fuel (2% HGVs and 10% buses in 2006, rising to 10% and 50% in 2010)	-0.149
9	Hybrid passenger cars (10% of new car sales)	-6.77	Hybrid passenger cars (10% of new car sales)	-0.119
10	Revised speed policy for motorways	-1.30	Retrofit CNG for heavy duty vehicles	-0.055
11	Hybrid buses (low NOx/PM option)	-1.24	Revised speed policy for motorways	-0.012
12	Low Emission Zones	-1.17	Bus lanes/guided busways (high estimate)	-0.007
13	Hybrid buses (low CO_2 option)	-0.62	Lorry road charging	-0.007
14	Lorry road charging	-0.36	Hybrid buses (low NOx/PM option)	-0.006
15	Access control - private car restrictions	-0.05	Access control - private car restrictions	-0.005
16	Car clubs	-0.04	Hybrid buses (low CO_2 option)	-0.004
17	Bus lanes/guided busways (high estimate)	-0.03	Car clubs	-0.001
18	Bus lanes/guided busways (low estimate)	0.00	Bus lanes/guided busways (low estimate)	-0.001
19	Biofuels (5% uptake)	0.00	Biofuels (5% uptake)	0.000
20	Biofuels (5.75% uptake)	0.00	Biofuels (5.75% uptake)	0.000

As can be seen from the table, the rank ordering differs depending on whether abatement of NOx or PM_{10} emissions is considered. However, it is clear that retrofit SCR, EGR, and Water Diesel Emulsion fuel for heavy-duty vehicles are the three options that have the best NOx and PM_{10} emissions abatement performance.

In addition to impacts on NOx and PM_{10} emissions, the analysis has also investigated the effect that the different options have on CO_2 emissions. As can be seen from Table 7.2 below, the rank ordering of options with regard to changes in CO_2 emissions is very different to the ranking presented for NOx and PM_{10} emissions.

Table 7.2: Rank ordering of options with respect to CO_2 emissions abatement performance

Rank	Option	Change in CO_2 emissions 2005-2010 (kiloTonnes)
1	Hybrid passenger cars (40% of new car sales)	-5358
2	Biofuels (5.75% uptake)	-3110
3	Hybrid passenger cars (10% of new car sales)	-1735
4	Biofuels (5% uptake)	-2120
5	Lorry road user charging scheme	-253
6	Car clubs	-116
7	Hybrid buses (low CO_2 option)	-76
8	Retrofit SCR + Diesel particulate filter for heavy duty vehicles	0
9	Water Diesel Emulsion fuel (10% HGVs and 100% of buses from 2006)	0
10	Water Diesel Emulsion fuel (2% HGVs and 10% buses in 2006, rising to 10% and 50% in 2010)	0
11	Scrappage scheme for pre-Euro and Euro 1 cars	0
12	Low Emission Zones	0
13	Revised speed policy for motorways*	0
14	Hybrid buses (low NOx/PM option)	0
15	Access control - private car restrictions*	0
16	Bus lanes/guided busways (high estimate)*	0
17	Bus lanes/guided busways (low estimate)*	0
18	Retrofit EGR + Diesel particulate filter for heavy duty vehicles	+219
19	Euro V (Scenario C) (DfT)	+301
20	Retrofit CNG for heavy duty vehicles	+1788

* Change in CO2 emissions unknown for these options but has been assumed to be zero for the purposes of this analysis

7.3 Monetary value of emissions abatement performance

The next step in the analysis was to apply monetary values to the changes in NOx, PM_{10}, and CO_2 emissions. The monetary valuation of NOx and PM_{10} emissions relates to the health benefits that accrue from reduced emissions of these two pollutants. This was discussed in more detail in Section 2.7.1. For NOx emissions, a single UK-wide figure can be used per tonne of pollutant. For PM_{10} emissions, it has been necessary to take into account the likely geographical split of emissions benefits, as reductions in PM_{10} emissions in highly populated areas have a greater economic value than reductions in rural areas. The geographical distributions of PM_{10} benefits that would arise from the implementation of each option have been estimated using projected vehicle kilometre data (split by DfT Area Type) from the Department for Transport's National Transport Model. For both NOx and PM_{10} emissions, the central high valuations of emissions benefits have been used. For CO_2 emissions, the valuation is based on values for the social costs of carbon, as discussed in more detail in Section 2.7.2.

The total economic value of the NOx, PM_{10}, and CO_2 emissions benefits of each option has been expressed as the Net Present Value of benefits over the 2005-2010 time period.

By combining the monetary valuations for NOx, PM_{10}, and CO_2 emissions, it is possible to rank the options in terms of the total emissions benefits. The results of this analysis are presented below in Table 7.3.

Table 7.3: Ranking of options for the 2005-2010 time period based on monetary value of emissions benefits*

Rank	Option	Monetary value of changes in NOx, PM_{10}, and CO_2 emissions (£millions)
1	Scrappage scheme for pre-Euro and Euro 1 cars	-£228.32
2	Low emission passenger cars (40% of new car sales)	-£199.93
3	Low Emission Zones	-£195.78
4	Retrofit SCR + Diesel particulate filter for heavy duty vehicles	-£147.17
5	Retrofit EGR + Diesel particulate filter for heavy duty vehicles	-£123.28
6	Water Diesel Emulsion fuel (10% HGVs and 100% of buses from 2006)	-£113.48
8	Euro 5 (Scenario C)	-£59.65
9	Biofuels (5.75% uptake)	-£57.61
7	Low emission passenger cars (10% of new car sales)	-£54.36
10	Water Diesel Emulsion fuel (2% HGVs and 10% buses in 2006, rising to 10% and 50% in 2010)	-£48.92
11	Biofuels (5% uptake)	-£38.87
12	Revised speed policy for motorways	-£20.96
13	Lorry road charging	-£6.58
14	Bus lanes/guided busways (high estimate)	-£5.67
15	Access control - private car restrictions	-£3.71
16	Hybrid buses (low CO_2 option)	-£3.23
17	Hybrid buses (low NOx/PM option)	-£2.99
18	Car clubs	-£2.63
19	Bus lanes/guided busways (low estimate)	-£0.42
20	Retrofit CNG for heavy duty vehicles	£12.06

* Emissions benefits are expressed as negative costs. Emissions increases are expressed as positive costs

As can be seen from the table, combining the NOx, PM_{10}, and CO_2 emissions benefits significantly alters the rank ordering of options, as a number of options that lead to large reductions in NOx or PM_{10} emissions, lead to an increase in CO_2 emissions. However, in order to come up with a final ranking of the options, it is necessary to take into account the implementation costs associated with each option and set these against the value of the emissions benefits that can be achieved (see Table 7.4). Those options that lead to the greatest net benefits to society (as expressed in monetary terms) are the options that should be prioritised for further investigation.

Table 7.4: Rank ordering of options based on net benefits and net costs to society* between 2005 and 2010

Rank	Option	Net Present Value of total implementation costs (2005-2010) (£millions)	Net Present Value of changes in NOx, PM_{10}, and CO_2 emissions (2005-2010) (£millions)	Net costs or benefits (2005-2010) (£millions)
1	Low Emission passenger cars (40% of sales) (Low cost estimate)	-£647.87	-£199.93	-£847.80
2	Low Emission passenger cars (40% of sales) (High cost estimate)	-£350.84	-£199.93	-£550.77
3	Low Emission passenger cars (10% of sales) (Low cost estimate)	-£211.72	-£54.36	-£266.07
4	Low Emission passenger cars (10% of sales) (High cost estimate)	-£115.51	-£54.36	-£169.86
5	Speed policy motorways (low cost estimate)	£2.92	-£20.96	-£18.04
6	Low Emission Zones (low cost estimate)	£188.45	-£195.78	-£7.34
7	Speed policy motorways (high cost estimate)	£20.00	-£20.96	-£0.96
8	Access control - private car restrictions	£12.41	-£3.71	£8.70
9	Retrofit CNG for heavy duty vehicles	-£3.15	£12.06	£8.91
10	Car clubs	£20.33	-£2.63	£17.70
11	Bus lanes/guided busways (low estimate)	£29.75	-£0.42	£29.33
12	Hybrid buses (low Carbon option)	£35.12	-£3.23	£31.89
13	Bus lanes/guided busways (high estimate)	£45.15	-£5.67	£39.48
14	Retrofit EGR + DPF (low cost estimate)	£163.99	-£123.28	£40.71
15	Hybrid buses (low NOx/PM option)	£45.20	-£2.99	£42.21
16	Retrofit SCR + DPF (low cost estimate)	£204.25	-£147.17	£57.08
17	Euro 5 (Scenario C)	£146.66	-£59.65	£87.01
18	WDE fuel (2% HGVs and 10% buses in 2006, rising to 10% and 50% in 2010)	£148.08	-£48.92	£99.16
19	Low Emission Zones (high cost estimate)	£325.53	-£195.78	£129.75
20	WDE fuel (10% HGVs and 100% of buses from 2006)	£353.46	-£113.48	£239.98
21	Retrofit EGR + DPF (high cost estimate)	£366.18	-£123.28	£242.90
22	Retrofit SCR + DPF (high cost estimate)	£390.88	-£147.17	£243.71
23	Scrappage scheme (low cost estimate)	£1,141.72	-£228.32	£913.40
24	Biofuels (5% uptake)	£1,659.60	-£38.87	£1,620.73
25	Scrappage scheme (high cost estimate)	£2,283.45	-£228.32	£2,055.12
26	Biofuels (5.75% uptake)	£2,516.14	-£57.61	£2,458.54
27	Lorry road charging (low cost estimate)	£2,603.38	-£6.58	£2,596.80
28	Lorry road charging (high cost estimate)	£2,740.34	-£6.58	£2,733.76

*Net benefits are expressed as negative monetary values. Net costs are expressed as positive monetary values.

In addition to analysing the options using a net costs and benefits approach, further analysis has also been carried out to rank the options using the Benefit to Cost Ratio (BCR) methodology. The Treasury Green Book recommends this approach when there is a budget constraint on which options can be implemented. The results of this analysis are presented in Table 7.5 below, and it can be seen that the overall rank ordering of options differs from that obtained using the net present value of benefits approach, although the first seven options are ranked in the same order regardless of the methodology used. It should be noted that because there are no net implementation costs associated with some options (i.e. total capital and operating costs are lower than the business as usual scenario), the BCR cannot be fully quantified. In effect, there are no costs and only benefits for these options and hence a ratio cannot be defined.

Table 7.5: Rank ordering of options based on Benefit to Cost Ratio

Rank	Option	Benefit to Cost Ratio
1	Low Emission passenger cars (40% of sales) (Low cost estimate)	Unquantifiable, but very high*
2	Low Emission passenger cars (40% of sales) (High cost estimate)	Unquantifiable, but very high*
3	Low Emission passenger cars (10% of sales) (Low cost estimate)	Unquantifiable, but very high*
4	Low Emission passenger cars (10% of sales) (High cost estimate)	Unquantifiable, but very high*
5	Speed policy motorways (low cost estimate)	7.185 :1
6	Speed policy motorways (high cost estimate)	1.048 :1
7	Low Emission Zones (low cost estimate)	1.039 :1
8	Retrofit EGR + DPF (low cost estimate)	0.752 :1
9	Retrofit SCR + DPF (low cost estimate)	0.721 :1
10	Low Emission Zones (high cost estimate)	0.601 :1
11	Euro 5 (Scenario C)	0.407 :1
12	Retrofit SCR + DPF (high cost estimate)	0.377 :1
13	Retrofit EGR + DPF (high cost estimate)	0.337 :1
14	WDE fuel (2% HGVs and 10% buses in 2006, rising to 10% and 50% in 2010)	0.330 :1
15	WDE fuel (10% HGVs and 100% of buses from 2006)	0.321 :1
16	Access control - private car restrictions	0.299 :1
17	Scrappage scheme (low cost estimate)	0.200 :1
18	Car clubs	0.129 :1
19	Bus lanes/guided busways (high estimate)	0.126 :1
20	Scrappage scheme (high cost estimate)	0.100 :1
21	Hybrid buses (low Carbon option)	0.092 :1
22	Hybrid buses (low NOx/PM option)	0.066 :1
23	Biofuels (5% uptake)	0.023 :1
24	Biofuels (5.75% uptake)	0.023 :1
25	Bus lanes/guided busways (low estimate)	0.014 :1
26	Lorry road charging (low cost estimate)	0.003 :1
27	Lorry road charging (high cost estimate)	0.002 :1
28	Retrofit CNG for heavy duty vehicles	0.000

* No additional implementation costs therefore there are only monetary benefits and a BCR cannot be quantified

It is clear from these analyses that all of the scenarios for the deployment of low emission passenger cars lead to the greatest net benefits, even taking into account uncertainty in the additional unit costs of these vehicles over conventional current passenger cars. Based on this analysis, only two other options lead to net economic benefits; reducing speed limits on sections of motorway near to major urban areas, and implementing Low Emission Zones in London and the largest urban centres in the UK. However, it should be borne in mind that for Low Emissions Zones, the analysis only indicated that there were net benefits on the basis of the low cost estimate for implementing such schemes.

At the other end of the scale, it is also clear that for options such as lorry road user charging, increased uptake of biofuels, and the scrappage scheme for pre-Euro and Euro 1 vehicles, the implementation costs significantly outweigh the monetary value of the emissions benefits that could be achieved. This is not surprising if one considers that neither the lorry road user charging scheme, nor increased uptake of biofuels are options that are specifically targeted at reducing emissions of NOx and PM_{10}. The lorry charging scheme has the aim of ensuring that all HGVs that operate on UK roads (whether they are UK or foreign-registered) contribute their fair share towards the costs of maintaining and improving the UK road network via the taxation system. To this end, it is anticipated that the introduction of the scheme will not have a significant effect on total annual HGV kilometres travelled, and hence the impact on total emissions from road transport will be small. However, it is thought that the costs associated with implementing and operating this scheme will be relatively high.

In this analysis, the increased uptake of biofuels has been assumed to have no effect on NOx and PM_{10} emissions, but there is a significant reduction in CO_2 emissions from their use. The economic benefits of these reductions have been taken into account, but these benefits are dwarfed by the very large implementation costs associated with increasing the use of these types of fuels.

If the scrappage scheme for pre-Euro and Euro 1 vehicles is assessed purely in terms of the economic value of the emissions benefits that would accrue from its implementation, it is the best performing scheme. However, based on the assumptions made for the financial incentives that would be necessary for such a scheme, it is clear that the costs of operating the scheme significantly outweigh the emissions benefits. This is primarily because the costs of the scheme are based on the financial incentives being available to the owners of all pre-Euro and Euro 1 passenger cars, including those who would have scrapped their vehicles without the availability of a financial incentive. It has also been assumed that the scheme would only lead to an additional 10% of pre-Euro and Euro 1 vehicles being scrapped in each year between 2005 and 2010. So, whilst in this analysis, the net costs of implementing the scheme appear to significantly outweigh the emissions benefits, the scale of the emissions benefits possible with this type of scrappage scheme means that further analysis of the deployment scenario should perhaps be carried out to provide a more detailed and accurate assessment of the implementation costs and scheme effectiveness.

7.4 Additional costs and benefits in the 2010 to 2025 time period

Many of the options that could be implemented between 2005 and 2010 will also have emissions benefits during the 2011-2025 time period. For this reason, an initial analysis of the cost and emissions benefits during the 2011-2025 time period has also been carried out for those options that are likely to still be providing emissions benefits during this later time period (see Table 7.6).

Table 7.6: Rank ordering of options based on net benefits and net costs to society between 2011 and 2025

Rank	Option	Net Present Value of total implementation costs (2011-2025) (£millions)	Net Present Value of changes in NOx, PM_{10}, and CO_2 emissions (2011-2025) (£millions)	Net costs or benefits (2011-2025) (£millions)
1	Low Emission passenger cars (40% of sales) (Low cost estimate)	-£12,448.64	-£4,192.87	-£16,641.51
2	Low Emission passenger cars (40% of sales) (High cost estimate)	-£4,218.37	-£4,192.87	-£8,411.24
3	Low Emission passenger cars (10% of sales) (Low cost estimate)	-£3,237.01	-£1,067.87	-£4,304.88
4	Low Emission passenger cars (10% of sales) (High cost estimate)	-£1,123.85	-£1,067.87	-£2,191.73
5	Speed policy motorways (low cost estimate)	£4.38	-£29.39	-£25.02
6	Speed policy motorways (high cost estimate)	£30.01	-£29.39	£0.62
7	Retrofit CNG for heavy duty vehicles	-£125.65	£139.82	£14.17
8	Access control - private car restrictions	£26.83	-£6.93	£19.91
9	Car clubs	£79.48	-£8.73	£70.75
10	Bus lanes/guided busways (low estimate)	£74.38	-£0.61	£73.77
11	Bus lanes/guided busways (high estimate)	£112.87	-£8.34	£104.54
12	Low Emission Zones (low cost estimate)	£156.79	-£45.50	£111.30
13	Retrofit EGR + DPF (low cost estimate)	£360.91	-£158.26	£202.65
14	Low Emission Zones (high cost estimate)	£258.76	-£45.50	£213.26
15	Retrofit SCR + DPF (low cost estimate)	£474.61	-£213.38	£261.23
16	Retrofit EGR + DPF (high cost estimate)	£684.49	-£158.26	£526.23
17	Retrofit SCR + DPF (high cost estimate)	£773.30	-£213.38	£559.91
18	WDE fuel (2% HGVs and 10% buses in 2006, rising to 10% and 50% in 2010)	£740.02	-£43.56	£696.46
19	WDE fuel (10% HGVs and 100% of buses from 2006)	£1,375.43	-£58.17	£1,317.26
20	Hybrid buses (low Carbon option)	£2,713.46	-£110.08	£2,603.38
21	Hybrid buses (low NOx/PM option)	£3,239.53	-£65.55	£3,173.98
22	Lorry road charging (low cost estimate)	£8,155.23	-£31.35	£8,123.89
23	Lorry road charging (high cost estimate)	£8,550.69	-£31.35	£8,519.34
24	Euro 5 (Scenario C)	£16,250.84	-£6,648.21	£9,602.64

*Net benefits are expressed as negative monetary values. Net costs are expressed as positive monetary values.

It can be seen from this analysis of costs and benefits for the 2010-2025 time period that low emission passenger cars would lead to the greatest net benefits (as they would during the 2005-2010 time period). Likewise, revisions to urban motorway speed policy have also been estimated to produce net financial benefits, but Low Emission Zones would, during this time period, have costs greater than the monetary value of emissions benefits. This is because unless the emissions standards associated with an LEZ are upgraded over time, the emissions abatement performance of such a scheme diminishes (due to the continuous renewal of the vehicle fleet) until it reaches a point where it provides no additional benefits over the baseline situation. For the proposed LEZ schemes assessed for this study, the point at which the scheme provides no additional emissions benefits is from 2015 onwards; between 2011 and 2014, the reductions in NOx and PM_{10} emissions are much lower than between 2007 and 2010, but the annual costs associated with the scheme would be the same. Hence, the scheme costs start to outweigh the emissions benefits.

7.5 Summary of findings

The cost benefit analysis carried out for this study has allowed the options for the 2005-2010 time period to be assessed using more traditional techniques than the Multi-Criteria Analysis used in Section 6. Based on the results obtained from this work, a list of options that should be investigated in further detail has been identified. This list consists of those options for which the monetary value of the emissions benefits outweighs the associated implementation and operating costs. The options proposed for further investigation based on the outputs of the cost benefit analysis are listed in below.

1. Low emission passenger cars
2. Revised speed policy for motorways close to urban areas
3. Low emission zones

In addition to those schemes where the benefits outweigh the costs, the scrappage scheme may also be worthy of further investigation, based on the very large benefits that would be possible from such a scheme.

8 Combinations of options

8.1 Overview

The results of both the Multi-Criteria Analysis and the Cost-Benefit Analysis have been used to identify a prioritised list of options for further investigation. For options identified for the 2005-2010 time period, it has been possible to extend the analysis further to start assessing the costs and emissions implications of combining different options. This section of the report presents the results of this analysis, which has been carried out using a cost-benefit approach. It must be stressed that the results from this work should be viewed as initial results; the approach taken has been to simply sum the costs and benefits of the various prioritised options. Whilst this gives an initial indication of the possible impacts, a much more rigorous approach should be used to fully investigate the implications of combining options, as there is the very real danger of double counting costs or emissions benefits.

8.2 Analysis of option combinations for the 2005-2010 time period

The most promising options identified from the Multi-Criteria Analysis and from the Cost-Benefit Analysis are presented below in Table 8.1 and Table 8.2.

Table 8.1: Prioritised list of individual options for further investigation as identified using Multi-Criteria Analysis

Option Reference	Option
MCA 1	Scrappage scheme for pre-Euro/Euro 1 cars (low cost estimate)
MCA 2	Retrofit SCR for heavy duty vehicles (low cost estimate)
MCA 3	Low emission passenger cars (10% of new car sales by 2010)

Table 8.2: Prioritised list of individual options for further investigation as identified using Cost-Benefit Analysis

Option Reference	Option
CBA 1	Low emissions passenger cars
CBA 2	Revised speed policy for motorways close to urban areas
CBA 3	Low Emission Zones

As can be seen from the tables, one scenario is common to the MCA and CBA prioritised lists – namely increased uptake of low emission passenger cars.

Estimates for the effect on baseline road transport emissions of combinations of options are provided in Table 8.3 below. These estimates are based on simply summing the emissions abatement performance of the individual options, using the figures presented in Section 3 of the report.

Table 8.3: Estimated impact of combinations of scenario options on UK road transport emissions

Combination Reference	Combinations of options	Estimated Change in NOx emissions 2005-2010 (kiloTonnes)	Estimated Change in PM_{10} emissions 2005-2010 (kiloTonnes)	Estimated Change in CO_2 emissions 2005-2010 (kiloTonnes)
MCA1 + MCA2	Scrappage scheme for passenger cars + Retrofit SCR for heavy duty vehicles	-131.80	-3.842	0
MCA1 + MCA3	Scrappage scheme for passenger cars + Low emission passenger cars (10% of new car sales by 2010)	-83.44	-2.573	-1735
MCA2 + MCA3	Retrofit SCR for heavy duty vehicles + Low Emission passenger cars (10% of new car sales by 2010)	-61.91	-1.806	-1735
MCA1 + MCA2 + MCA3	Scrappage scheme for passenger cars + Retrofit SCR for heavy duty vehicles + Low Emission passenger cars	-138.58	-4.111	-1735
CBA1 + CBA2	Low emission passenger cars + Revised speed policy for motorways in urban areas	-16.42	-0.356	-1735
CBA1 + CBA3	Low emission passenger cars + Low Emission Zones	-14.21	-1.839	-1735
CBA2 + CBA3	Revised speed policy for motorways in urban areas + Low Emission Zones	-17.08	-1.658	0
CBA1 + CBA2 + CBA3	Low emission passenger cars + Revised speed policy for motorways in urban areas + Low Emission Zones	-23.85	-1.927	-1735
MCA1 + CBA2	Scrappage scheme for passenger cars + Revised speed policy for motorways in urban areas	-86.31	-2.393	0
MCA1 + CBA3	Scrappage scheme for passenger cars + Low Emission Zones	-84.10	-3.875	0
MCA1 + MCA2 + MCA3 + CBA3	Scrappage scheme for passenger cars + Retrofit SCR for heavy duty vehicles + Low Emission passenger cars + Low Emission Zones	-146.01	-5.681	-1735

These results have been further analysed to provide the monetary value of potential emissions benefits from each combination of options, using the same methodology described in Section 2.7 and in Section 7. The results of this analysis have been used to rank the options in terms of the monetary value of emissions benefits possible between 2005 and 2010 (Table 8.4 below). As might be expected, the greatest emissions benefits would be achieved by combining a larger number of options. However, it is also clear that combinations of two options, where one of the options is the scrappage scheme for pre-Euro and Euro 1 cars, are likely to provide large emissions benefits. In particular, it can be seen that the second highest ranked combination consists of the scrappage scheme with increased uptake of low emission passenger cars.

Table 8.4: Ranking of option combinations based on net present value of emissions benefits between 2005 and 2010

Reference	Combination of options	Net Present Value of emissions benefits between 2005 and 2010 (£millions)	Ranking
MCA1 + MCA2 + MCA3 + CBA3	Scrappage scheme for passenger cars + Retrofit SCR for heavy duty vehicles + Low Emission passenger cars + Low Emission Zones	-£625.63	1
MCA1 + MCA2 + MCA3	Scrappage scheme for passenger cars + Retrofit SCR for heavy duty vehicles + Low Emission passenger cars	-£429.85	2
MCA1 + CBA3	Scrappage scheme for passenger cars + Low Emission Zones	-£428.59	3
MCA1 + MCA2	Scrappage scheme for passenger cars + Retrofit SCR for heavy duty vehicles	-£375.49	4
MCA1 + MCA3	Scrappage scheme for passenger cars + Low emission passenger cars (10% of new car sales by 2010)	-£282.68	5
CBA1 + CBA2 + CBA3	Low emission passenger cars + Revised speed policy for motorways in urban areas + Low Emission Zones	-£271.10	6
CBA1 + CBA3	Low emission passenger cars + Low Emission Zones	-£250.14	7
MCA1 + CBA2	Scrappage scheme for passenger cars + Revised speed policy for motorways in urban areas	-£249.29	8
CBA2 + CBA3	Revised speed policy for motorways in urban areas + Low Emission Zones	-£216.75	9
MCA2 + MCA3	Retrofit SCR for heavy duty vehicles + Low Emission passenger cars (10% of new car sales by 2010)	-£201.52	10
CBA1 + CBA2	Low emission passenger cars + Revised speed policy for motorways in urban areas	-£75.32	11

*Emissions benefits are expressed in terms of negative monetary values.

Whilst the above table indicates the likely value of emissions benefits, it is also important, as with the cost-benefit analysis of individual options, to begin to assess the total costs associated with combinations of options. It must again be stressed that this analysis of costs and benefits is very much an initial investigation, and it is strongly recommended that further, more detailed analysis of the costs and benefits of scenario combinations is required. However, Table 8.5 and Table 8.6 below present initial assessments of the net costs or benefits of option combinations, taking into account a range of values for the costs of implementing options, and setting these against the monetary value of emissions benefits that could be achieved between 2005 and 2010. The option combinations have been ranked twice: once based on lower estimates for option costs, and the second time based on upper estimates for option costs.

Table 8.5: Ranking of option combinations based on net costs and benefits (ranking based on lower estimates for option costs)

Combination Reference	Combination of options	Net costs or benefits (2005-2010) (Low estimate for option cost)	Net costs or benefits (2005-2010) (High estimate for option cost)	Ranking
CBA1 + CBA2 + CBA3	Low emission passenger cars + Revised speed policy for motorways in urban areas + Low Emission Zones	-£293.94	-£43.56	1
CBA1 + CBA2	Low emission passenger cars + Revised speed policy for motorways in urban areas	-£282.12	-£168.83	2
CBA1 + CBA3	Low emission passenger cars + Low Emission Zones	-£275.89	-£42.60	3
MCA2 + MCA3	Retrofit SCR for heavy duty vehicles + Low Emission passenger cars (10% of new car sales by 2010)	-£207.00	£75.84	4
CBA2 + CBA3	Revised speed policy for motorways in urban areas + Low Emission Zones	-£29.86	£124.31	5
MCA1 + MCA3	Scrappage scheme for passenger cars + Low emission passenger cars (10% of new car sales by 2010)	£649.32	£1,887.25	6
MCA1 + MCA2 + MCA3 + CBA3	Scrappage scheme for passenger cars + Retrofit SCR for heavy duty vehicles + Low Emission passenger cars + Low Emission Zones	£694.58	£2,256.23	7
MCA1 + MCA2 + MCA3	Scrappage scheme for passenger cars + Retrofit SCR for heavy duty vehicles + Low Emission passenger cars	£706.40	£2,130.96	8
MCA1 + CBA2	Scrappage scheme for passenger cars + Revised speed policy for motorways in urban areas	£895.36	£2,054.17	9
MCA1 + CBA3	Scrappage scheme for passenger cars + Low Emission Zones	£901.58	£2,180.39	10
MCA1 + MCA2	Scrappage scheme for passenger cars + Retrofit SCR for heavy duty vehicles	£970.48	£2,298.83	11

*Net benefits are expressed as negative monetary values. Net costs are expressed as positive monetary values.

Table 8.6: Ranking of option combinations based on net costs and benefits (ranking based on upper estimates for option costs)

Combination Reference	Combination of options	Net costs or benefits (2005-2010) (Low estimate for option cost)	Net costs or benefits (2005-2010) (High estimate for option cost)	Ranking
CBA1 + CBA2	Low emission passenger cars + Revised speed policy for motorways in urban areas	-£284.12	-£170.82	1
CBA1 + CBA2 + CBA3	Low emission passenger cars + Revised speed policy for motorways in urban areas + Low Emission Zones	-£291.45	-£41.07	2
CBA1 + CBA3	Low emission passenger cars + Low Emission Zones	-£273.41	-£40.11	3
MCA2 + MCA3	Retrofit SCR for heavy duty vehicles + Low Emission passenger cars (10% of new car sales by 2010)	-£208.99	£73.85	4
CBA2 + CBA3	Revised speed policy for motorways in urban areas + Low Emission Zones	-£25.38	£128.79	5
MCA1 + MCA3	Scrappage scheme for passenger cars + Low emission passenger cars (10% of new car sales by 2010)	£647.33	£1,885.26	6
MCA1 + CBA2	Scrappage scheme for passenger cars + Revised speed policy for motorways in urban areas	£895.36	£2,054.17	7
MCA1 + MCA2 + MCA3	Scrappage scheme for passenger cars + Retrofit SCR for heavy duty vehicles + Low Emission passenger cars	£704.41	£2,128.97	8
MCA1 + CBA3	Scrappage scheme for passenger cars + Low Emission Zones	£906.06	£2,184.87	9
MCA1 + MCA2 + MCA3 + CBA3	Scrappage scheme for passenger cars + Retrofit SCR for heavy duty vehicles + Low Emission passenger cars + Low Emission Zones	£697.07	£2,258.72	10
MCA1 + MCA2	Scrappage scheme for passenger cars + Retrofit SCR for heavy duty vehicles	£970.48	£2,298.83	11

*Net benefits are expressed as negative monetary values. Net costs are expressed as positive monetary values.

As can be seen from the results of this analysis, combinations that include low emission passenger cars come out very favourably, with the four most highly ranked combinations all including this option. Whilst combinations that included the scrappage scheme were very highly ranked when the analysis was based solely on the monetary value of emissions abatement, it is clear from this analysis that there are high estimated implementation costs associated with such schemes, as option combinations including the scrappage scheme all have net costs, rather than net benefits associated with them.

8.3 Option combinations for the 2011-2025 time period

For the 2011-2025 time period, only Multi-Criteria Analysis has been used to rank and prioritise options for further detailed investigation, primarily because there was a lack of cost and emissions abatement data for all options under consideration. Hence, unlike for the 2005-2010 time period, it has not been possible to use cost-benefit analysis techniques to help in selecting combinations of options for further investigation. The results of the Multi-Criteria Analysis identified the following options as the “most preferred”:

Table 8.7: Prioritised list of individual options for further investigation as identified using Multi-Criteria Analysis

Ranking	Option
1	Increased uptake of battery-electric vehicles
2	New diesel formulations
3	Integrated land use and transport planning

Whilst the results of the Multi-Criteria Analysis prioritised the above three options, and these individual options should be investigated further to try to identify costs and emissions benefits in more detail, it is not clear that combinations of these three options will necessarily work well together. An initial examination of some of the other, less favoured, options for this time period has indicated that it may be better to include some of them in any combinations that are proposed. In particular, packages of options that combine incentives with new transport restrictions or financial penalties may work particularly well. Particular examples that should be considered for further investigation include combinations based around the proposed national road-pricing scheme. The scheme aims to improve traffic congestion by introducing distance/time-based charges for all road users. Possible options that may work well with this scheme include more use of integrated land use and transport planning to try to reduce the need for travel, or the introduction of emissions trading schemes for HGVs/taxis and personal carbon accounts.

As an individual option, extended Low Emission Zones did not rank very highly within the list of possible scenarios for 2011-2025. However, a number of the other options for this time period, could, if combined with extended Low Emission Zones, provide significant reductions in emissions. If it is assumed that extended Low Emission Zones would still be focused on heavy-duty vehicles, then it is clear that measures that help to remove such vehicles from urban areas would complement this option. In particular, it is proposed that a combination of extended Low Emission Zones with increased use of freight distribution centres on the outskirts of urban areas to transfer loads to smaller goods vehicles for final delivery may work well. This combination could be further reinforced by the introduction of an emissions trading scheme for HGVs. If there is increased availability of battery-electric heavy duty vehicles or hydrogen fuel cell vehicles during the 2011-2025 time period, then there will be the opportunity for extended Low Emission Zones to be augmented even further.

At this stage, it is not possible to quantify what the costs or emissions benefits would be of introducing any of the packages of options proposed above, as detailed emissions modelling and cost information would be required. Table 8.8 summarises the option combinations that are recommended for further, more detailed investigation.

Table 8.8: Recommended combinations for the 2011-2025 time period of scenario options for further investigation (Note: not ranked in order of preference)

Combinations of options for further investigation
* National road pricing scheme + Integrated land use and transport planning * National road pricing scheme + Emissions trading scheme for HGVs/taxis * National road pricing scheme + Personal Carbon accounts * National road pricing scheme + Integrated land use and transport planning + Emissions trading scheme for HGVs/taxis + personal carbon accounts * Extended LEZs + increased use of freight distribution centres * Extended LEZs + + Emissions Trading Scheme for HGVs * Extended LEZs + battery electric heavy duty vehicles + H_2 fuel cell vehicles for captive fleets * Extended LEZs + battery electric heavy duty vehicles + H_2 fuel cell vehicles for captive fleets + Emissions Trading Scheme for HGVs

8.4 Option combinations for the 2025-2050 time period

As for the 2011-2025 time period, only Multi-Criteria Analysis was used to rank and prioritise the options for the 2025-2050 time period. The results of the five MCA runs that were carried out led to the following list of prioritised options being developed.

Table 8.9: Prioritised list of individual options for further investigation as identified using Multi-Criteria Analysis

Ranking	Option
1	Large-scale uptake of hydrogen fuel cell vehicles
2	Fuel duty differential based on life cycle emissions
3	Scrappage scheme for petrol and diesel vehicles

During this time period, it is anticipated that the widespread uptake of hydrogen fuel cell vehicles will occur. This is of course dependent on the technology being available at a price and performance level that is comparable to conventional internal combustion engine technology. Furthermore, during this time period, options that can mitigate climate change impacts are likely to become increasingly important. Assuming that this is the case, then options based on hydrogen technology, or that favour non-petroleum based transport fuels will be favoured. It is therefore not surprising to see that the three the most favoured options, as identified by the multiple MCA runs carried out on all options for this time period, are based on encouraging or increasing the use of renewable and non-petroleum fuel sources. It is recommended that the prioritised options listed above could be combined to form a mutually beneficial package to accelerate the uptake of hydrogen-based transport, and to speed the removal of conventional petrol and diesel fuel.

Table 8.10: Recommended combination for the 2025-2050 time period of scenario options for further investigation

Combination of options for further investigation	
1	Large-scale uptake of hydrogen fuel cell vehicle + fuel duty differentials based on life-cycle emissions + scrappage scheme for petrol and diesel vehicles

9 Study conclusions and recommendations

9.1 Overview

This study has been used to identify prioritised lists of individual technical and non-technical options that could be used to help the UK meet upcoming and future emissions and air quality limit values in three time periods: 2005-2010, 2011-2025, and 2025-2050. Multi-Criteria Analysis and Cost Benefit Analysis techniques have been used to carry out the ranking and prioritisation process. Additionally, the results of the analyses of individual options have been used to propose possible combinations of options, and (where possible) provide an initial assessment of the costs and emissions benefits associated with these combinations. Outputs from this study will be used to inform the review of the Air Quality Strategy.

9.2 Prioritised options for the 2005-2010 time period

9.2.1 Identification of individual options for further investigation

For the **2005-2010 time period**, based on the results of the cost-benefit analysis, the following three options were prioritised (in rank order of importance) for further study.

1. Increased uptake of low emission passenger cars
2. Revised speed policy for motorways close to urban areas
3. Low Emission Zones

Using a Multi-Criteria Analysis approach for the assessment of options, the following three options were prioritised (again in rank order of importance).

1. Scrappage scheme for pre-Euro and Euro 1 passenger cars
2. Retrofit Selective Catalytic Reduction (with diesel particulate filter) for heavy-duty vehicles
3. Increased uptake of low emission passenger cars

Low emission passenger cars appear on both lists and hence a total of five options have been prioritised for further study. The rank ordering of the five options is dependent on whether the five options are assessed using cost-benefit analysis or multi-criteria analysis. Table 9.1 below provides a summary of the results of applying cost-benefit analysis to the five prioritised options. As can be seen from the Table, increased uptake of low emission passenger cars leads to the greatest net benefits (taking into account implementation costs and reductions in both pollution damage costs and the social costs of carbon emissions), whilst at the other end of the scale, scrappage schemes incur the greatest net costs.

Table 9.1: Costs and benefits associated with the five prioritised options for the 2005-2010 time period

Ranking	Option	Net Present Value of total implementation costs (2005-2010) in £millions	Net Present Value of changes in NOx, PM_{10}, and CO_2 emissions (2005-2010) in £millions	Net costs or benefits (2005-2010) in £millions
1	Increased uptake of low emission passenger cars	-£647.87 to -£115.51	-£199.93 to -£54.36	**-£847.80 to -£169.86**
2	Revised speed policy for motorways close to urban areas	£2.92 to £20.00	-£20.96	**-£18.04 to -£0.96**
3	Low Emission Zones	£188.45 to £325.53	-£195.78	**-£7.34 to £129.75**
4	Retrofit SCR (with DPF) for heavy-duty vehicles	£204.25 to £390.88	-£147.17	**£57.08 to £243.71**
5	Scrappage scheme for pre-Euro and Euro 1 passenger cars	£1,141.72 to £2,283.45	-£228.32	**£913.40 to £2,055.12**

*NOTE: negative values indicate benefits and positive values indicate costs.

The use of multi-criteria analysis allows the options to be assessed against a wider range of parameters than just costs and emissions benefits. Traffic impacts, social parameters, and the practicality of introducing individual options have all been assessed using this methodology, along with impacts on costs and emissions. However, the analysis is limited by the fact that a qualitative approach must be taken with respect to many of these parameters. Table 9.2 below provides an overview of the results of applying a multi-criteria analysis approach to assessing these options, in order to demonstrate how this analysis technique produces a different ranking of options compared to the cost-benefit analysis discussed above.

Table 9.2: MCA scores and rankings associated with the five prioritised options for the 2005-2010 time period

Ranking	Option	MCA Total scores (out of a possible maximum of 100)	
		Upper score	Lower score
1	Scrappage scheme for pre-Euro and Euro 1 passenger cars	55.9	52.5
2	Increased uptake of low emission passenger cars	53.8	52.7
3	Retrofit SCR (with DPF) for heavy-duty vehicles	53.6	51.0
4	Low Emission Zones	46.1	44.1
5	Revised speed policy for motorways close to urban areas	37.1	36.9

In Table 9.2, the two MCA scores for each option relate to different scenarios assumptions – in particular, they reflect where upper and lower cost estimates have been used.

It is clear that using a cost-benefit analysis approach produces a different rank ordering to the multi-criteria analysis approach and it is difficult to resolve this issue to arrive at a single, ranked list of prioritised options. The cost-benefit methodology uses a rigorous analytical approach to estimate which of the options produces the greatest net monetary benefits, but the approach is limited by the fact that it solely concentrates on costs and emissions reductions and does not include any of the wider impacts of the options. The multi-criteria analysis approach on the other hand provides an assessment of costs, emissions abatement performance, and the wider impacts of the different options, but is limited by the fact that qualitative data has to be used where quantitative data is unavailable. Bearing all of this in mind, it would not be appropriate to try to provide an overall ranking of the options based on trying to combine the results of the two different analytical methods, as the ranking is wholly dependent on the analysis method used. However, it is clear that increased uptake of low emission passenger cars is an option that ranks highly both from the results of the cost benefits analysis and from the multi-criteria analysis, and it is strongly recommended that this option is given the greatest priority for further investigations. With regard to further work on this option, there is a need to define in more detail the various different types of low emission passenger cars. For this study, the term has been used to cover hybrid electric cars, and vehicles that are fitted with emissions abatement technology, and further work should be focused on defining emission factors for the individual low emission technologies so that a more complete assessment of the costs and emissions benefits associated with increased uptake of these types of vehicles can be carried out. Further work will also be required to develop more detailed uptake scenarios for these types of vehicles.

9.2.2 Identification of combinations of options for further investigation

An assessment of the monetary value of the emissions benefits that could be achieved from combinations of these options has identified that for the **2005-2010 time period,** combinations that include the scrappage scheme for pre-Euro and Euro 1 cars lead to very large reductions in emissions benefits. However, once the estimated scheme costs are set against the emissions benefits, packages that include the scrappage scheme perform relatively poorly. By contrast, combinations that include increased uptake of low emission passenger cars have the greatest overall net benefits. As there is some level of uncertainty regarding the costs and emissions performance of combinations of options, it is recommended that for the 2005-2010 time period, more detailed assessments should primarily be carried out for option combinations that include increased uptake of low emission passenger cars. A list of prioritised option combinations for further investigation (including initial estimates of net benefits) is provided in Table 9.3 overleaf.

Table 9.3: Prioritised option combinations for the 2005-2010 time period

Ranking	Combination of options	Net costs or benefits (2005-2010) (Low estimate for option cost) in £millions	Net costs or benefits (2005-2010) (High estimate for option cost) in £millions
1	Low emission passenger cars + Revised speed policy for motorways in urban areas	-£284.12	-£170.82
2	Low emission passenger cars + Revised speed policy for motorways in urban areas + Low Emission Zones	-£291.45	-£41.07
3	Low emission passenger cars + Low Emission Zones	-£273.41	-£40.11
4	Retrofit SCR for heavy duty vehicles + Low Emission passenger cars	-£208.99	£73.85
5	Revised speed policy for motorways in urban areas + Low Emission Zones	-£25.38	£128.79

9.3 Prioritised options for the 2011-2025 time period

9.3.1 Identification of individual options for further investigation

For the **2011-2025 time period**, there were much less quantitative data available on the costs and emissions abatement performance of individual options, and hence Multi-Criteria Analysis was used to rank and prioritise options for further investigation. The results of this ranking process have led to the identification of three prioritised individual scenario options. These are as follows:

1. Increased uptake of battery-electric vehicles
2. New diesel formulations
3. Further integrated land use and transport planning

It is recommended that further investigations are carried out for these options to try to identify in more detail the costs and emissions benefits associated with them.

9.3.2 Identification of combinations of options for further investigation

With regard to combining options into packages, it is not thought that a combination of the three prioritised individual options listed above would provide any useful synergies that could be exploited to support the aims of any one option. Instead, it has been proposed that some of the options that were individually ranked much less favourably may be usefully combined to obtain additional benefits. It is recommended that combinations of options based around the proposed national road-pricing scheme and potential extended LEZ schemes should be investigated in detail. A list of recommended option combinations for further investigation is provided in the table below.

Table 9.4: Recommended option combinations for the 2011-2025 time period

Combinations of options for further investigation
* National road pricing scheme + Integrated land use and transport planning
* National road pricing scheme + Emissions trading scheme for HGVs/taxis
* National road pricing scheme + Personal Carbon accounts
* National road pricing scheme + Integrated land use and transport planning + Emissions trading scheme for HGVs/taxis + personal carbon accounts
* Extended LEZs + increased use of freight distribution centres
* Extended LEZs + + Emissions Trading Scheme for HGVs
* Extended LEZs + battery electric heavy duty vehicles + H_2 fuel cell vehicles for captive fleets
* Extended LEZs + battery electric heavy duty vehicles + H_2 fuel cell vehicles for captive fleets + Emissions Trading Scheme for HGVs

9.4 Prioritised options for the 2025-2050 time period

9.4.1 Identification of individual options for further investigation

For the 2025-2050 time period, no quantitative data were available on the costs and emissions abatement performance of options, so in the same manner as for the 2011-2025 time period, Multi-Criteria Analysis was used to rank and prioritise the individual options. The highest-ranked individual options are listed below:

1. Large-scale uptake of hydrogen fuel cell vehicles
2. Fuel duty differentials based on life-cycle emissions
3. Scrappage scheme for petrol and diesel vehicles

9.4.2 Identification of combinations of options for further investigation

For this time period, it is likely that reducing CO_2 emissions will be of greater importance than improvements to air quality, and all three of the prioritised options would help to reduce CO_2 emissions. With regard to suitable packages of options, it has been recommended that the impacts of a combination of all three options should be investigated further, as the individual options are likely to complement and reinforce the effects of the others.

Table 9.5: Recommended option combination for the 2025-2050 time period

Combination of options for further investigation	
1	Large-scale uptake of hydrogen fuel cell vehicle + fuel duty differentials based on life-cycle emissions + scrappage scheme for petrol and diesel vehicles

9.5 Modelling the air quality benefits of urban transport measures

The study has contributed to the review of the Air Quality Strategy by prioritising measures based on their costs, emissions abatement performance, and wider impacts in order that further analysis can be carried out on the most promising options. However, it is important to reiterate that this work has been carried out to assess options that could be used to help the UK meet upcoming NO_2 and PM_{10} *pollutant concentration* limit values, but the analysis has necessarily had to focus on the impacts that options have on NOx and PM_{10} *emissions*. Further work will be required to assess the impact that the prioritised options have on pollutant concentrations using more detailed emissions analysis coupled with air quality modelling techniques. Estimates of the emissions abatement performance of different options can be used as input data for air quality modelling to quantify the effects that specific options would have on pollutant concentrations. Typically, such modelling would use, as part of the input data, emission projections based on average vehicle emission factors for future years (taking into account new technologies and future vehicle emission standards), and traffic growth parameters for future years obtained from the Department for Transport's (DfT's) National Transport Model (NTM). These traffic growth parameters relate to specific "area types" within the NTM, and hence cover relatively large geographical areas that may not provide the required level of resolution for some urban transport measures. Furthermore, air quality modelling at the national scale makes use of a modelling grid with a 1 km x 1 km resolution, which combined with the emissions projection methodology described above, may not give a high enough level of resolution to fully quantify the air quality benefits of some options in urban areas. In particular, it is thought likely that reductions in urban pollutant concentrations associated with measures such as Low Emission Zones, access control measures, and measures to improve the emissions performance of urban buses may be underestimated using the above methodology. Further research will be required to resolve this issue.

9.6 Other study recommendations

The study has also highlighted the need for a more detailed investigation of the impacts of technical options on primary NO_2 emissions. Continuously Regenerating Trap (CRT) diesel particulate filter technology is known increase the proportion of NOx emitted as NO_2, which in turn leads to higher roadside NO_2 concentrations. This has important implications for the manner in which future NO_2 pollutant concentrations are predicted. The air quality modelling methods that AEA Technology's Netcen operating division carries out in support of policy development make use of empirically-based assessments of the ratio between NO_2 and NOx concentrations at roadside locations (based on automatic monitoring station measurements of the NO_2:NOx concentration ratio). This methodology implicitly takes account of current primary NO_2 emissions, but has the disadvantage that any increases in the proportions of direct NO_2 emissions in future years due to the uptake of new technologies, are not taken into account in NO_2 concentration projections for future years. Sensitivity analysis from previous work has indicated that increased primary NO_2 emissions would lead to an increase in roadside NO_2 concentrations. Further work is therefore required to understand in detail the impacts that options have on primary and total NO_2 emissions (particularly in urban areas), and the consequent impacts on NO_2 concentrations. In the first instance, this would cover all options where a CRT diesel particulate filter could be fitted to vehicles. Of the prioritised options for the 2005-2010 time period, this includes:

- Low emission passenger cars
- Low Emission Zones
- Retrofit Selective Catalytic Reduction (with diesel particulate filter) for heavy duty vehicles

References

[1] Council Directive 96/62/EC of 27 September 1996 on ambient air quality assessment and management, Official Journal L 296, 21/11/1996 P. 0055 - 0063

[2] Council Directive 1999/30/EC of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air, Official Journal L 163, 29/06/1999 P. 0041 - 0060

[3] Nitrogen Dioxide in the United Kingdom, Air Quality Expert Group (April 2004); UK air quality modelling for annual reporting 2002 on ambient air quality assessment under Council Directives 96/62/EC and 1999/30/EC, AEA Technology Environment (September 2003)

[4] S Kollamthodi and L Middlemiss, (AEA Technology Environment), “Review of Technical and Non-technical Options for Reducing Emissions from Road Transport, July 2004

[5] National Atmospheric Emissions Inventory, www.naei.org.uk

[6] P Watkiss et al, “The London Low Emission Zone Feasibility Study”, AEA Technology Environment, July 2003

[7] P Watkiss, G Jones, and S Kollamthodi, (AEA Technology Environment), “An Evaluation of the Air Quality Strategy: Additional Analysis – Local Transport Measures”, December 2004

[8] European Commission Communication Document COM (2000) 379, Social Policy Agenda, 28th June 2000.

[9] P Watkiss *et al*, (AEA Technology Environment) “An Evaluation of the Air Quality Strategy”, January 2005

[10] R Clarkson and K Deyes, Estimating the Social Costs of Carbon Emissions, Government Economic service Working paper 140, January 2002

[11] Initial Regulatory Impact Assessment for a forthcoming proposal for a European directive concerning emissions standards for new light duty vehicles, Department for Transport, October 2004

[12] Vehicle Licensing Statistics 2003, Department for Transport

[13] Feasibility Study of Road Pricing in the UK, Department for Transport, July 2004

[14] A McKinnon, “Lorry Road User Charging: a Review of the UK Government’s Proposals”, Heriot-Watt University, May 2004

[15] The Auto-Oil II Programme, European Commission DG Economic and Financial Affairs, DG Enterprise, DG Transport and Energy, DG Research, and DG Taxation and Customs Union, October 2000

[16] Scottish Transport Statistics 2002

[17] Commission for Integrated Transport, “European Comparison of Taxes on Car Ownership and Use”, July 2001

[18] National Automated Highway System Research Program A Review, TRB Special Report 253 (1998) http://gulliver.trb.org/publications/sr/sr253.html

[19] http://www.camdek.com/index.html