Air4EU

Air Quality Assessment for Europe: from local to continental scale

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Traffic Management impact in London, using OSCAR

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1. Executive Summary

Road traffic has continually increased over the past two decades and has become a major source of air pollution in urban areas. In order to control the related traffic air pollution, traffic management is required. Within the framework of traffic management for air pollution control, several measures of pollution reduction are available such as changing of vehicle technologies, fleet compositions, traffic behaviours and impact of background concentrations. In this report, the OSCAR system, containing meteorological pre-processor, emissions model and various levels of street pollution models, has been employed to demonstrate the impact of measures for reducing road traffic related air pollution. The measures utilised in this report are based on the default/embedded options in the OSCAR system which include emissions/scenario, traffic contributions to air pollution, sensitivity to background concentrations and future projections. Although the changes of EU traffic emission standard such as EURO standards are available, these modules have not been analysed in this report. Nevertheless, the measures used in this study have shown the percentage reduction of traffic source pollutants and the possibility of identifying possible ways of reducing traffic air pollution.

2. Case study description

2.1 Background

Road transport has been identified as the most important source of air pollution in urban areas (Kukkonen, et al., 2001, EEA, 2006). It is the main source of pollutants such as nitrogen oxides (NOx), volatile organic counpunds (VOCs), particulate matter (PM) and carbon monoxide (CO) as well as carbon dioxide (CO_2). According to the study of Haq and Bailey, 1999, the road transport of freight and passengers in the EU countries has increased by approximately 45% and 41%, respectively, since the early 1980s. Road transport, particularly freight and passenger transports in Western Europe, are predicted to double between 1990-2010. Hence, local authorities need to take control of road traffic in order to control air pollution in urban areas effectively.

This report focuses on two main pollutants, nitrogen dioxide (NO_2) and particulate matter (PM10). NO_2 is recognised as an important urban pollutant in most European cities. According to the EU First Daughter Directive (99/30/EC), an annual limit of 40 µg m^{-3} has been set and 200 µg m^{-3} as an hourly limit not to be exceeded more than 18 times per year. In the UK, local authorities have indicated traffic to be the most important source of NO_2 (Carslaw, 2005). The exceedences of such pollutants are still detected particularly at the roadside (Stedman, et al., 2001).

PM_{10} is particulate matter with an aerodynamic diameter of 10 µm or less. It causes adverse effects on human health and is covered under the EC air quality daughter directive with a limit value of 40 µg m^{-3} for the annual mean and 50 µg m^{-3} 24-h mean not to be exceeded more than 35 times per year (Mediavilla-Sahagún and ApSimon, 2003, DEFRA, 2003, EU Directives 96/62/EC, 99/30/EC, 2000/69/EC). In a London study, road vehicles, especially the Heavy Goods Vehicles (HGVs), buses and petrol cars, were shown to play a major role in contributing to primary PM_{10} pollution (Mediavilla-Sahagún and ApSimon, 2006).

To address the concerns over air quality due to road vehicles, effective traffic management is required. Traffic management will impact on local air quality involves in identifying what local measures will reduce street levels of PM_{10} and NO_2. In order to undertake such as study, a range of input data (e.g. emission factors; various European/national data sources; background concentrations) and models need to be considered. In this report the OSCAR System Air Quality Assessment System (Sokhi, et al, 2007) has been applied to a London street a case study.

2.2 Aim and description

The aim of this study is to demonstrate how the impact of traffic management strategies can be assessed for a real urban case. It does not examine different models and their merits but focuses on a methodology for undertaking such studies. It considers the change in local pollution levels due to the emission changes as a result of changes of fleet composition and driving pattern such as traffic speed. It is expected that the contribution of urban background to local air quality is also be assessed.

2.3 Relevance to recommendations in Air4EU

Modelling:

- It is important to evaluate the models before undertaking an assessment study, It is also important that the models are evaluated for similar conditions and locations as the assessment study area.
- Care should be taken to ensure that the background concentration represents the pollution being transported into the local area investigated
- For annual values models with simple empirical treatment of chemistry can be used for screening assessment purposes;
- For effective air quality management strategies models can be used to examine the impact of specific and individual pollution reduction measures as well as the combination of the measures.

3. Methodology

The OSCAR system is an integrated system to support the assessment of the impacts of road traffic on local air quality. It integrates a suite of models and a toolkit containing a meteorological pre-processor, emissions module, a scenario analysis tool and a visualisation module. It is designed to provide various assessment options depending on the complexity of the problem and the availability of input data. Urban and regional scale models may also be employed to estimate background contributions on a local scale. Further details can be found in Sokhi, et al, (2007) but some of key features are summarised below.

3.1 Components in OSCAR System

OSCAR system contains several components for local air quality management through database, emission, street level models, and visualization/analysis tools. The diagram in Figure 1 shows how components in OSCAR system are constructed and interact with each other.

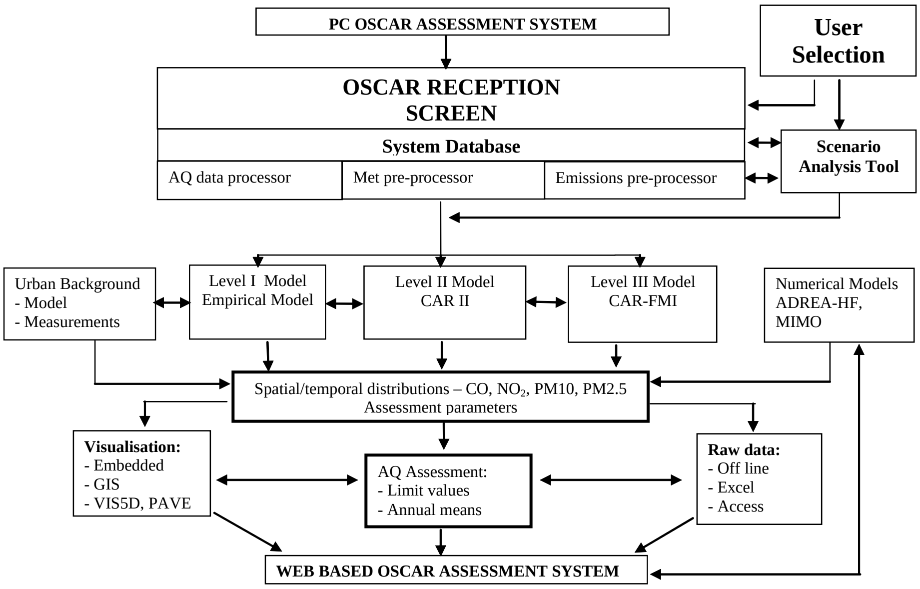

Figure 1. Main modules in the OSCAR System

The details of each component are described as follows:

i) OSCAR Reception/User Interface

The reception screen is the user interface linking the user to the tools, such as emission model, meteorological pre-processors, street models, data post-processing tools, available in the system. The Microsoft (MS) ACCESS database is embedded in the system to store input and output from the models. Urban background concentrations can be calculated through the system, or can be supplied as a user-defined file. Each of the available tools in OSCAR can be executed separately, for example, to estimate emissions or to analyse meteorological conditions over the area of interest.

ii) System Database

The MS ACCESS database is the embedded system database. Three major databases are integrated in the OSCAR system including the fleet composition database and national traffic profiles (hourly, weekly and monthly) and emission factors from COPERT III (Ntziachristos and Samaras, 2000). A database of the road links to be modelled is created from the input data supplied by the user. The data include coordinates of the road, the number of lanes, the lane width, the height of the buildings on the road, and the flow (volume and speed) and composition of traffic in terms of six vehicle categories: motorcycle, passenger car, light goods vehicles (LGVs), rigid heavy goods vehicles (HGVs), articulated HGVs and buses. The OSCAR System employs a link-based approach and hence the speed of the vehicles is taken to be the average value for the particular link.

Emission factors from COPERT III for CO, NO_x and particulate matter are used. These depend on parameters such as the type of the vehicle and the average speed. Some of the database entries (*e.g.* road link information and traffic profiles) are accessible directly from the main reception screen.

iii) Emission pre-processor

The emission pre-processor uses the traffic data for each road link and the emission factors to produce the emission input for the appropriate air quality model. The emission profiles for a range of European countries for future years based on TREMOVE are included in the system database.

In current version of OSCAR (v 1.14), PM_{10} and $PM_{2.5}$ emissions due to tyre wear, brake wear and road surface wear are calculated in addition to exhaust emissions of particulate matter. To calculate such emissions, the approaches reported in the European Environment Agency's Emission Inventory Guidebook (EEA, 2004) were used. The re-suspension of material deposited on the road surface has not yet been included in the OSCAR System.

OSCAR provides flexibility in emission data processing. The emission database has been constructed for both situations where the comprehensive traffic composition information and where only basic data are available. If only basic data, such as total volume of traffic or the split between LGVs and HGVs, are available, then the default composition profiles, incorporated into the system to yield a more detailed emission output, may be employed by the user.

iv) Meteorological pre-processor

The meteorological pre-processor (MPP) used in OSCAR system was developed based on approaches described in Bualert (2002). The MPP employs meteorological data, such as wind components and roughness, length and surface heat fluxes, to estimate atmospheric stability parameters, including the Monin-Obukhov Lengths and mixing heights. Alternatively, the simpler Pasquill-Gifford stability treatment can be used if the data are limited.

The MMP requires six meteorological input parameters: time (month, day, hour), wind speed (knots), wind direction (degrees), ambient temperature (°C), cloud cover (Okta) and global radiation (W m^{-2}). In combination with the constants values of surface characteristics; such as surface roughness, Bowen ratio, Albedo and anthropogenic heat flux, of three land cover categories (urban, suburban, and rural), the MPP then yields the meteorological dataset for such aforementioned land use types.

v) Street/Air Quality Models

OSCAR system provides several levels of air quality models. Level I model is a screening model, consisting of simple polynomial expressions for calculating NO_2 from NO_x concentrations, and multiple regression relationships for estimating street-level concentrations of CO and NO_x from traffic volumes and wind speed at a fixed receptor. Level II model is the CAR II which is based on simple empirical relationships between annual concentrations and basic parameters such as wind speed, traffic characteristics and road geometries. Level III model is the CAR-FMI, allowing finer resolution calculations of hourly concentrations at multiple receptors, and requires a more detailed treatment of meteorology. A higher level of model sophistication, including results from MIMO (Ehrhard, et. al. 2000) and ADREA-HF (Vlachogiannis et al., 2002) models; is also available via the OSCAR Web based system (http://www.eu-oscar.org). Computational Fluid Dynamic (CFD) approach is employed to deal with complex street geometries. This report does not discuss the Web System further, and focuses on the performance of the OSCAR Level II and III models. More details and validation of CAR II and CAR FMI models are described in section 3.3.

vi) Data Post-Processor

The air quality concentrations output from OSCAR system can be visualised using a range of graphical software packages. These include ArcView (ESRI, 2005) and the free software ‘Package for Analysis and Visualization of Environmental data’ (PAVE) (EMPD, 2005), providing enhanced data display and manipulation capabilities. ArcView, with ‘Spatial Analyst’ functionality, allows the air quality data to be visualised and analysed in terms of base geographical data, including road layout and traffic characteristics. A simple capability has also been developed in the OSCAR System to show the time series of concentrations for a quick, ‘first-look’ visualisation. A data analysis module calculates basic statistical parameters for each pollutant at a receptor location, including the maximum hourly concentration, the 98th percentile concentration, and the annual mean pollutant concentration.

vii) Scenario Analysis Tools

In OSCAR, emissions from traffic can be calculated corresponding to the changes of traffic volume and composition, mean speed and vehicle technology, such as reducing the heavily polluting vehicles (*e.g.* Pre-Euro I, Euro I) in favour of less polluting vehicles (e.g. Euro IV). The resulting changes in the emissions, meteorological conditions and background concentrations are taken into account by optional street models (CAR-International and Car-FMI) to calculate the air quality levels for selected road links or receptor points. The basic concept of using OSCAR for traffic management is summarised in Figure 2.

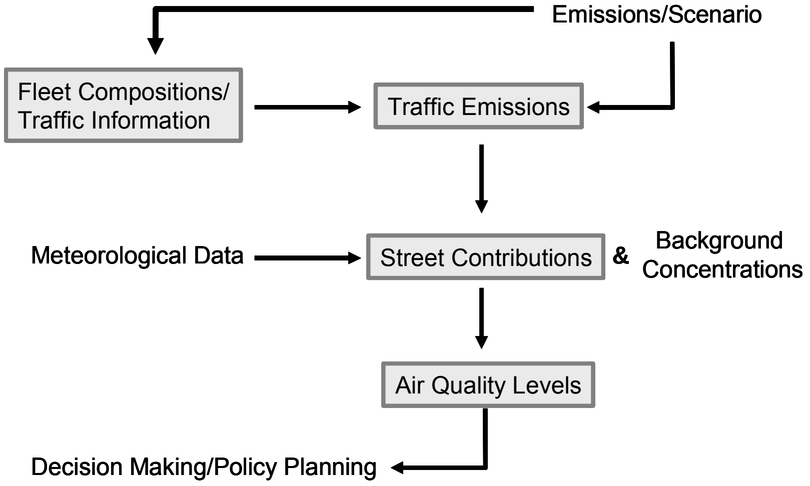

Figure 2: Concept of using OSCAR for assessing the impact traffic management strategies on local air quality.

3.2 Description and Validation of CAR-II and CAR FMI in OSCAR

Extending beyond previous section, mode details of CAR II and CAR-FMI are described in this section. The validations of CAR II and CAR-FMI carried out by previous studies; Sokhi et al. (2007), are also briefly shown.

i) CAR II

The CAR (Calculation of Air Pollution from Road Traffic) model is used to calculate the air quality in streets. The model takes into account the emission from traffic, street type (5 road types are considered in CAR such as open road and street canyon), the distance to the road axis and the annual average wind speed to calculate the traffic related contribution (Equation 1).

$$C_{Rd} = E \times \theta \times f_t \times \frac{5}{U} \tag{1}$$

Where C_{Rd} id traffic related contribution (ug m^{-3}), E is traffic emissions (ug/m/s), ϴ is dilution factor (s/m^2) depending on street type, F_t is a factor that accounts for the influence of trees on the wind speed and hence on dispersion and concentration, U is annual averaged wind speed (m/s). Total concentration can be calculated by adding background concentration to the traffic related concentration.

An empirical relationship between the traffic related NOx contribution ($C_{rd,NOx}$ in ug m^{-3}) and O_3 background concentration ($C_{bg,O3}$ in ug m^{-3}) are used to calculate traffic related NO2 contribution ($C_{rd,NO2}$ in ug m^{-3}) as shown in Equation (2) below:

$$C_{rd,NO2} = F_{NO2} \times C_{rd,NOx} + \frac{\beta \times C_{bg,O3} \times C_{rd,NOx} \times (1 - F_{NO2})}{C_{rd,NOx} \times (1 - F_{NO2}) + K} \tag{2}$$

where F_{NO2} is the fraction of NOx directly emitted as NO2 (approximately 5-10%), β and K are empirical parameters.

Input data required by CAR II include traffic information/link details, meteorological data (annual mean wind speed), annual emissions (CO, HC, NOx, CO_2, PM), and background concentrations (NO2, PM10m O3, SO2, BaP and CO. Annual concentrations of NO_2, PM_{10}, Benzene, SO_2, and CO 98 percentile are yielded by the model.

ii) CAR-FMI

CAR-FMI is a road network dispersion model developed base on the Gaussian finite-line source model approach (Karpinen, et al. 2000). An analytic solution of the Gaussian diffusion equation for the finite source is as follow:

$$C = \frac{Q_1}{2\sqrt{2\pi}\sigma_z u \sin\theta}\left[\exp\left(-\frac{(z-H)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z+H)^2}{2\sigma_z^2}\right)\right]\left[erf\left(\frac{\sin\theta(p-y) - x\cos\theta}{\sqrt{2}\sigma_y}\right) + erf\left(\frac{\sin\theta(p+y) + x\cos\theta}{\sqrt{2}\sigma_y}\right)\right] \tag{3}$$

where C is the concentration, Q_1 is the source strength per unit length, u is the average wind speed, ɵ is the angle between the wind direction and the road, *x*, *y* and *z* are the coordinates, *H* is the effective source height, *p* is the half-length of the line source, "erf" is the error function and σ_z and σ_y are the vertical and lateral dispersion parameters, respectively. These dispersion parameters are calculated as function of the Monin-Obukhov length, friction velocity and mixing height.

The model includes the basic reactions of nitrogen oxides, oxygen and ozone:

$$NO_2 + hv \xrightarrow{K_R} NO + O \qquad (4)$$

$$O + O_2 + M \longrightarrow O_3 + M \qquad (5)$$

$$NO + O_3 \xrightarrow{K_F} NO_2 + O_2 \qquad (6)$$

where M is a third body (most commonly nitrogen) and K_F and K_R are reaction rate constants which are functions of ambient temperature and solar radiation intensity. The influence of hydrocarbons on the transformation of nitrogen oxides is important on regional and long-range transport scales. On the urban scale, however, their influence is less significant, as the residence times of the air masses are too short for significant chemical transformations to take place (Kukkonen et al., 2001).

Input data needed by CAR-FMI include traffic information, meteorological data (hourly wind speed, wind direction, 1/L, Mixing height, Temperature, Global radiation, Relative humidity and atmospheric pressure), hourly emissions (NOx, CO, and PM for each particular road link), and hourly background concentrations (NO, NO_2, O_3, CO, $PM_{2.5}$). CAR-FMI output includes annual mean gridded concentrations for CO, NO_2, NO, O_3 and PM and hourly mean concentrations of NO, NO_2, NOx, CO, $PM_{2.5}$ at user selected receptor points.

iii) Evaluation of CAR II and CAR-FMI

The evaluations of CAR II and CAR FMI from the OSCAR system are carried out to validate the performance of such models for street air quality modelling hence traffic management. Examples of model validations shown in this section are based on the studies at Cromwell Road. More details of models validation at other cities which can be found in Sokhi et al. (2007).

Figure 3 shows the comparison between predicted (from CAR II and CAR-FMI) and observed annual mean concentrations of NO_2, $PM_{2.5}$ and PM_{10} for 2003 at Cromwell Road. Urban background concentrations were derived from North Kensington monitoring station.

Although the models slightly under-predicted the NO_2 concentration at Cromwell Rd, the models perform well for PM_{10} and $PM_{2.5}$ predictions. The under-predicted NO_2 concentrations may be caused by an underestimation of NOx emissions at the roadside sites, by uncertainties in the traffic composition, particularly HGVs and buses that emit one or two orders more NO_x than cars, or in the COPERT III emission factors. These possible causes of uncertainty were not investigated further as part of this case study.

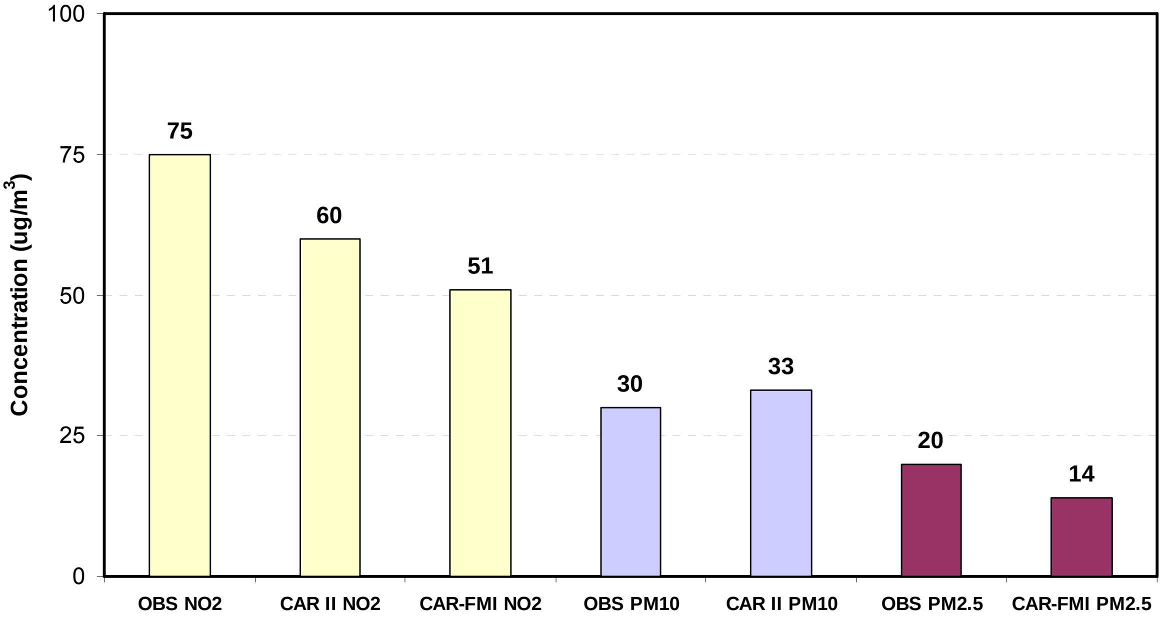

Figure 3: Comparison of CAR-FMI and CAR II modelled NO_2, $PM_{2.5}$ and PM_{10} annual mean concentrations (µg m-^{3}) with observations (Obs) at Cromwell Rd site for 2003

Based on Figure 4, good correlation is observed for $PM_{2.5}$ when compared to other pollutants with R_2 = 0.58. The model under-predicted the measurements by approximately 25%. It should be noted that the non-exhaust proportion of the PM has not been included in the calculation in this study. Regarding NO_x and NO_2 predictions, model also under-predicts the measurements which is probably due to under-estimation of emissions, possibly related to primary NO_2.

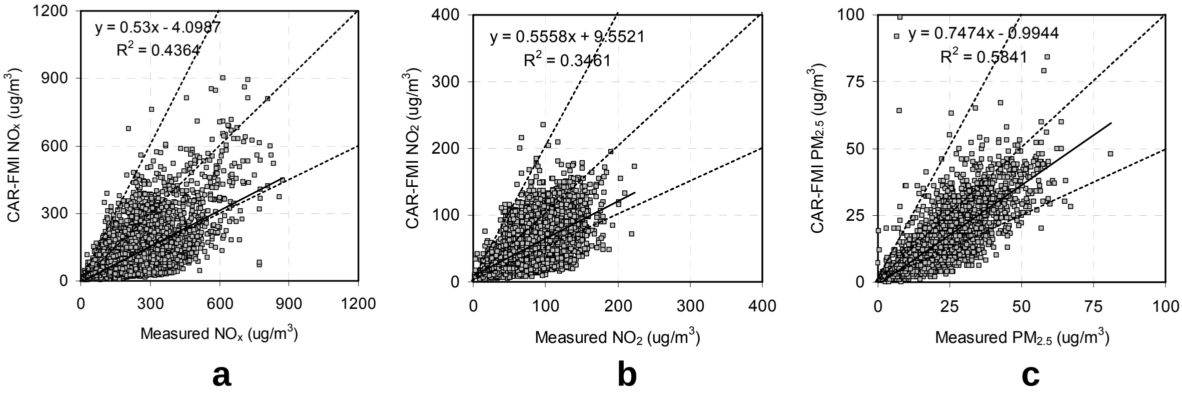

Figure 4: CAR-FMI modelled versus observed concentrations (µg/m^3) of (a) NO_x, (b) NO_2 and (c) $PM_{2.5}$ in Cromwell Road for 2003 (number of data points =8175 for NO_x and NO_2 and 3690 for $PM_{2.5}$). The dotted lines indicate the y=2x, y=x/2 and the y=x lines.

Table 1 shows the statistical measures for the CAR-FMI performance at Cromwell Rd. The Correlation Coefficient (CC), Index of Agreement (IA) between modelled values and observations is high. Normalised mean standard error (NMSE) indicates low deviations of predicted NO_2 and PM_{10} values from measurements while showing highest deviation of predicted NO_x values. Fraction bias (FB) and Factor of Exceedence (FOEX) indicate the model underpredicted the concentration. However, more than 50% of predicted values of all pollutants are within the factor of two lines as indicated by F2. Overall, the CAR-FMI performs well at Cromwell Rd.

Table 1: Statistical measures for CAR-FMI performance at Cromwell Road

Pollutant	CC	NMSE	IA	FB	FOEX	F2 (%)
$PM_{2.5}$	0.764	0.294	0.808	-0.356	-38	72
NO_2	0.588	0.366	0.674	-0.377	-35	72
NOx	0.660	0.921	0.670	-0.651	-42	56

3.3 London Case Study

The two streets characteristics; open road and street canyon, have been selected as the case study for London. These are Marylebone Road and Cromwell Rd as shown in Figure 5. The input data has included local traffic information to generate emissions, hourly meteorological data measured at London Weather Station and background concentrations based on year 2003 to calculate the annual (by CAR-II) and hourly (by CAR-FMI) concentrations of NO_2, NOx, $PM_{2.5}$ and PM_{10}.

Figure 5: Maps of study areas

Several emissions scenario options have been examined at these two streets sites. The measures expected to influence the changes of NO_2 and PM_{10} concentrations, include:

1. Emission scenarios
    - Reduction of cars in favour of public transport, e.g., buses
    - Reduction of HDVs
    - Effect of traffic speed on NOx and PM emissions and NO_2 and PM_{10} concentrations
2. Effects of background concentrations
3. Changes in the traffic volume on NO_2 and PM_{10} Concentrations

The assumed percentage reductions of these measures are set to 5%, 10%, 15% and 20% and the results are reported below in section 4.

4. Results

4.1 Meteorological Conditions

The meteorological dataset was obtained from London Weather Centre (LWC), which is sited in an urbanised part of London. Surface roughness length was set to 1.5 m at both sites. An anthropogenic heat flux of 10 W/m^2 was assumed to account for the higher temperatures observed in urban locations. Annual average wind speed at LWC was 3.9 m/s with wind direction frequency mainly from the southwest (20%), as shown in Figure 6.

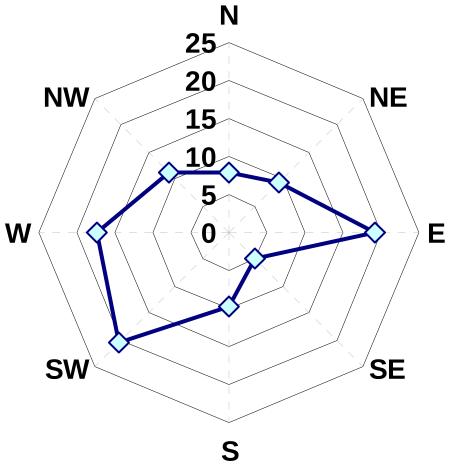

Figure 6: Wind direction frequency at measured at London Weather Centre, 2003

4.2 Fleet Compositions

Marylebone Road is characterised as a street canyon located in central London with traffic flows of over 80,000 vehicles per day on three lanes each way. For this study, forty-nine road links at Marylebone Road site were chosen. The summary of average fleet compositions is shown in Figure 7. The fleet composition was 78% car, 12% LGV, 3% HGVs, 2% bus, and the rest for motorcycle. Average speed of the traffic was about 22 km/h.

The Cromwell Road is classified as an open and flat urban street. The average daily traffic flows were 45,000 vehicles per day. The average fleet composition from 4 road links at Cromwell Road is shown in Figure 7 with 84% of the fleet being petrol cars, 9% LGVs, 1.8% rigid HGVs, 0.3% artic HGVs, ~2% buses, and the rest being motorcycles. The average vehicle speed is just over 16 km/h.

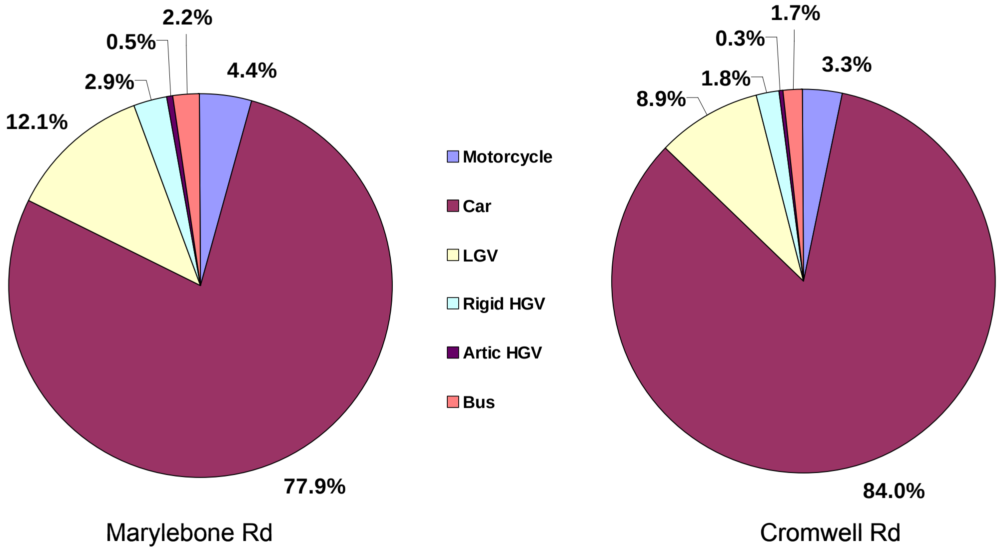

Figure 7: Fleet Composition at Marylebone Road (left) and Cromwell Road (right)

Air quality data was extracted from the UK Air Quality Archive (NETCEN) for year 2003 (DEFRA, 2007),for hourly NO_x as NO_2 concentrations at Marylebone Road and Cromwell Road sites, for the year 2003. Annual average for NO_x as NO_2 at Marylebone Rd and Cromwell Rd were 314 ug m^{-3} and 192 ug m^{-3}, respectively. The ratio of NO_x as NO_2 at Marylebone Rd and Cromwell Rd is 1.6 (annual) which approximately corresponds to the ratio of heavy duty vehicles at both sites.

4.3 Measures for Traffic Related Air Pollution Reduction

OSCAR system provides several measures of reduction of traffic related air pollution. The measures selected for the London case study include reduction of cars to public transports, reduction of HGVs, changes of traffic speeds, impacts of background concentrations, traffic contributions and future projections. The results for each measure are shown in the following sections.

i) Emission Scenarios

a) Reduce cars in favour of public transport

Cars present the largest proportion of vehicle categories used in cities like London. This category is an important factor in many problems including air pollution, traffic congestion, road accidents and noise pollution (Romilly, 1999). In the UK during 1999 – 2001, car travel was dominant over other forms of transportation at 63%, while only 6% was attributed to bus travel (Lucas, 2006). For policy maker, switching from the car to buses is a potential and effective way of reducing congestion and pollution.

OSCAR system has been used to measure percentage reduction of pollutants after substituting bus for car travel. The number of cars used (replaced by bus used), has been reduced by 5%, 10%, 15% and 20%. The emissions of NO_x and PM from traffic, hence NO_2 and PM_{10} concentrations (calculated from CAR II) are depicted in Figure 8 and Figure 9. The figures describe the emissions of NO_x and PM from traffic and suggest that reduction in emissions can be achieved of approximately 7% and 4%, respectively, when 20% of cars have been replaced by buses. The OSCAR System uses a simple default conversion factor for cars to buses but this can be easily changed by the users to reflect local behaviour patterns.

Similar figures are observed for NO_2 and PM_{10} concentrations. The difference is only that the percentage reduction of NO_2 concentration is slightly lower than percentage reduction of NO_x emissions. This is related to the ratio of NO_2 to NOx and O_3 background concentration used in CAR II. It should be noted that the OSCAR System includes a simple 5% figure for primary NO_2 emissions and any changes in this source caused by different measures was not investigated as part of this study.

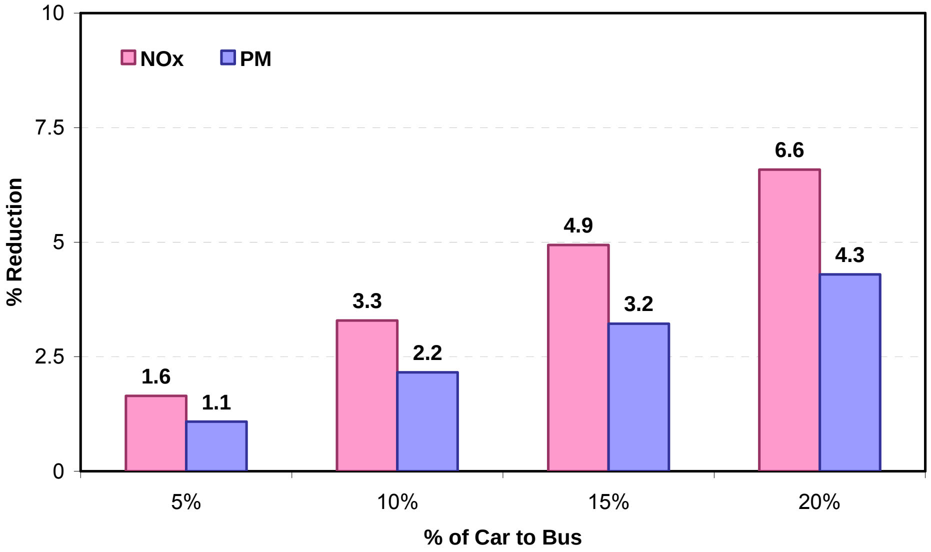

Figure 8: Changes of emissions at Marylebone Rd caused by reducing the number of cars in favour of buses *(street increments)*

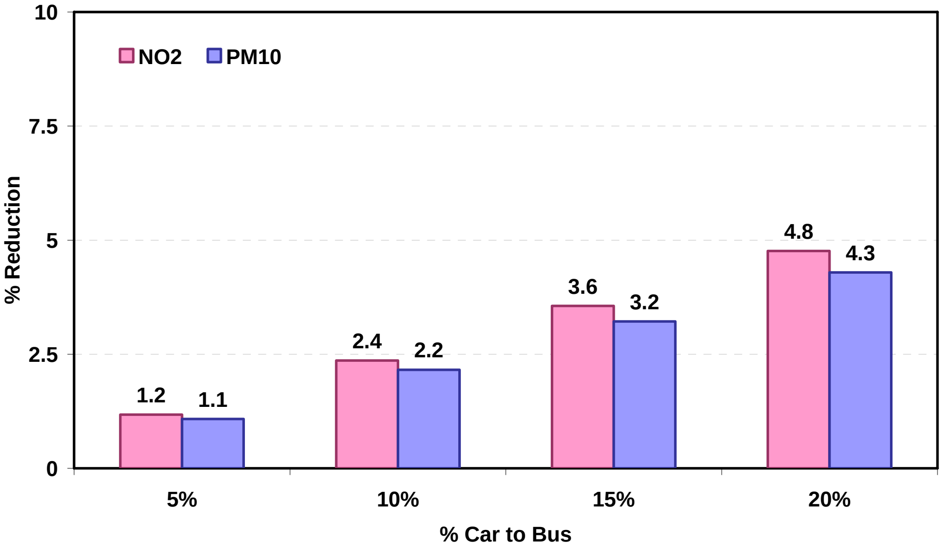

Figure 9: Changes of predicted NO_2 and PM_{10} concentrations (from CAR II) at Marylebone Rd caused by reducing the number of cars in favour of buses *(street increments)*

According to the results for CAR II and CAR-FMI at Cromwell Rd and Marylebone Rd, there is some difference in the percentage reductions predicted in the concentrations and emissions. The CAR-FMI results (not shown here) show slightly higher reduction levels. The differences, however, was not significant.

b) Reductions in HDVs

HDVs are one of the major sources of NOx and PM emissions. To control the level of such pollutants, the city authorities are interested in the effect of reducing the number of HDVs. According to the modelled results from the OSCAR system, a significant level of reduction can be achieved in the street emissions of NO_x and PM by reducing the number of HDVs. In Figure 10 and 11, the levels of NO_x and PM traffic emissions have decreased by up to 9% and 11% as a result of 20% reduction in the number of HDVs.

The NO_2 concentration have declined but at a lower percentage than NO_x emissions due to the chemical reactions with ozone.

The magnitude of street pollutant reductions due to lowering the number of HDVs is larger than the reduction of previous measure of limiting cars in favour of buses. From these results, the local authorities should consider the control of the number of HDVs on the road in order to improve the levels of street NO_x and PM concentrations.

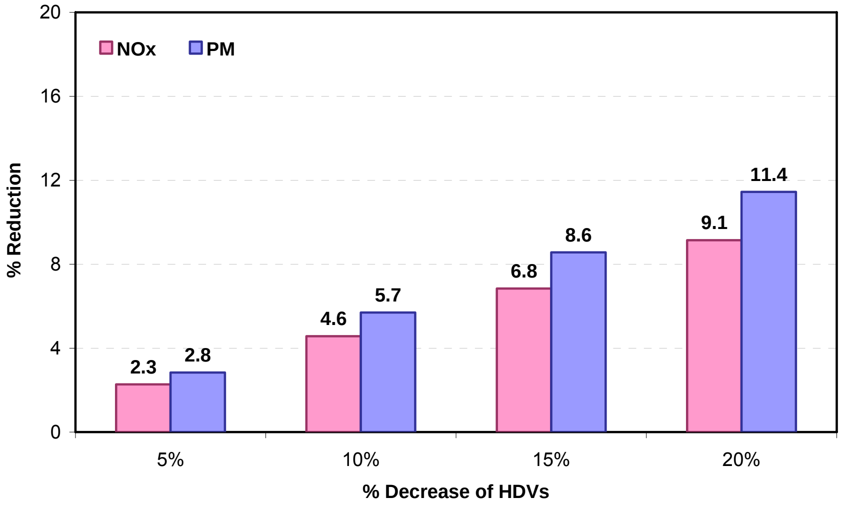

Figure 10: Effects of reducing HDVs on NO_x and PM emissions at Marylebone Rd, 2003 *(street increments)*

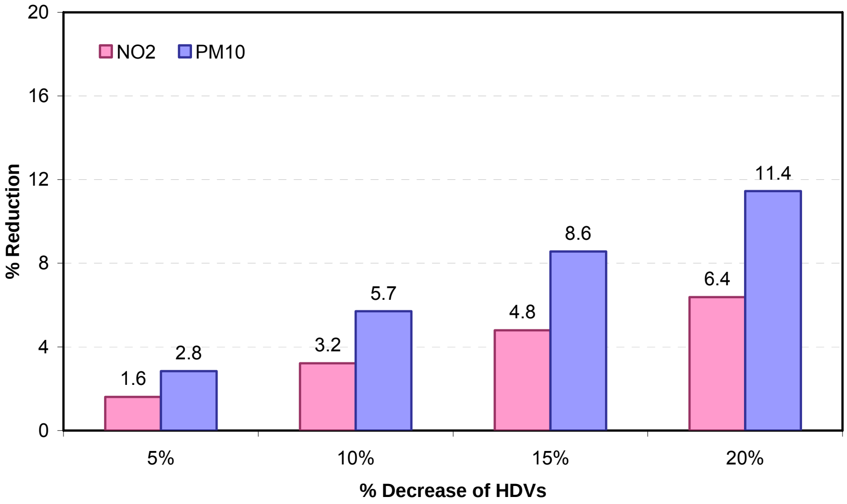

Figure 11: Effects of reducing HDVs on NO_2 and PM_{10} Concentrations predicted by CAR II at Marylebone Rd, 2003 *(street increments)*

c) Effect of traffic speed in emissions and air quality

Vehicle speed is one of the factors that play an important role on emission levels (see for example, Beevers and Carslaw, 2005). Based on Figure 12 and Figure 13, the effect of traffic speed on levels of street PM is greater than for NOx and NO_2 levels. Although the study suggests increasing the vehicle speeds will result in a reduction of pollutant emissions this is not the case when the speed has exceeded given threshold. As a result of the study with EURO II LGV, Euro III diesel and Euro IV petrol car reported by Beevers and Carslaw (2005), increasing speeds from 20 to 45 km/h does not affect NOx and PM emissions very much. Average traffic speed set in this study is approximately 22 km/h at Marylebone Rd. This study does however, imply that it is important to keep the traffic flowing rather than having vehicles moving at slow speeds or in very congested conditions.

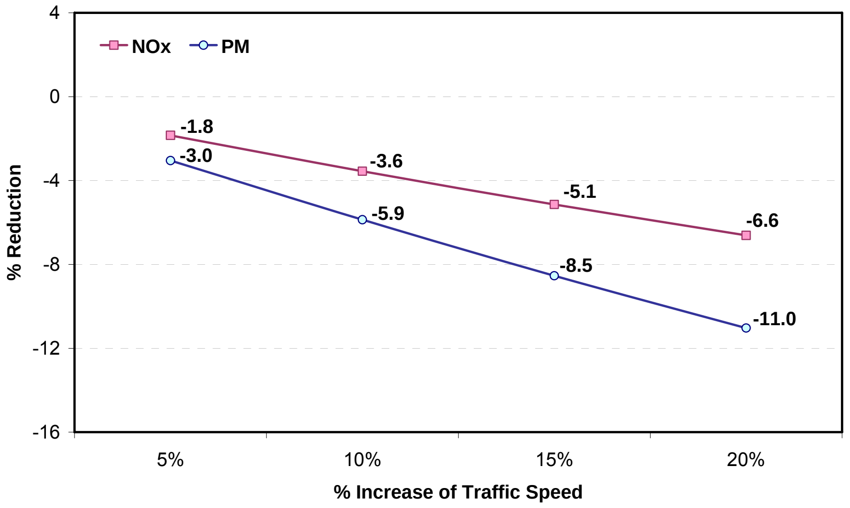

Figure 12: Percentages changes in predicted NO_x and PM emissions at Marylebone Rd, 2003 due to changes in traffic speeds *(street increments)*

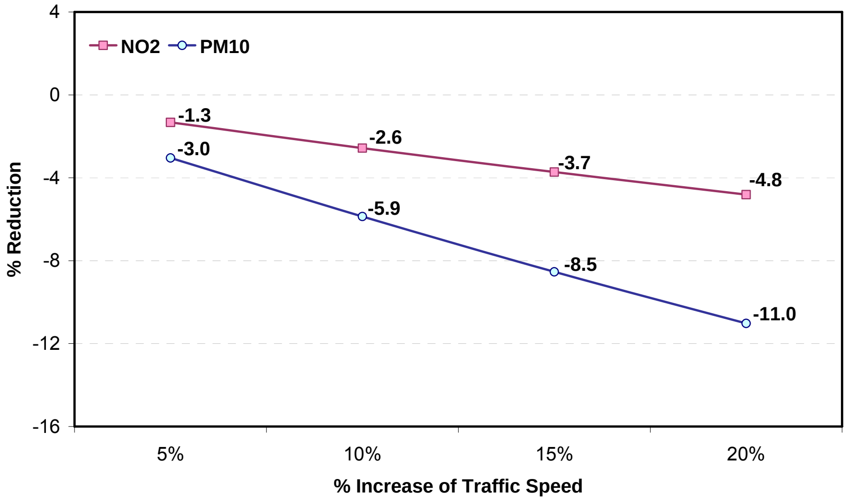

Figure 13: Percentages changes in predicted NO_2 and PM_{10} concentrations at Marylebone Rd, 2003 due to changes in traffic speeds calculated with CAR II *(street increments)*

ii) Sensitivity to background concentrations

Background concentration can be derived from two major sources; monitoring stations or through the use of models. This document reports on the sensitivity of CAR II prediction on changes on background concentrations of O_3 and NO_2 taken from two different urban background stations. Table 2 shows the background concentrations for base case study (61 μg m^{-3} for O_3 and 36 μg m^{-3} for NO_2), and background concentrations derived from London background monitoring station; Brent and North Kensington. First set of sensitivity tests involve changing NO_2 levels only (44 μg m^{-3} and 34 μg m_{-3}). Second set of sensitivity tests involve changing both O_3 and NO_2 background concentration with observed data taken from both N Kensington and Brent stations (37 μg m^{-3} for O_3, 44 μg m^{-3} for NO_2 and 42 μg m^{-3} for O_3, 34 μg m^{-3} for NO_2).

Table 2: Background concentrations for base case study and from monitoring stations

Case Study	**O_3 BG (µg m^{-3})**	**NO_2 BG (µg m^{-3})**
Base case Study	61	36
NO_2 from N Kensington	61	44
NO_2 BG from Brent	61	34
O_3 and NO_2 from N Kensington	37	44
O_3 and NO_2 from Brent	42	34

Figure 14 shows % changes in NO_2 concentration from base case study predicted by CAR II at Marylebone Rd. NO_2 concentration increases by 16% when background concentration is increased from 36 µg m^{-3} to 44 µg m^{-3} (a percentage increase of about 33%). The NO_2 concentration decreases by approximately 5% when background concentration of NO_2 was decreased from 36 µg m^{-3} to 34 µg m^{-3} (about 6%). The overall relative impact of background on street level NO_2 obviously will also depend on the magnitude of the street increment resulting direct local traffic emissions. This analysis shows that the NO_2 background concentration can have a measurable impact on the street level air quality even for streets which are subject to heavy traffic loads.

When lower O_3 background concentrations are used (from N Kensington station), that is 61 µg m^{-3} to 37 µg m^{-3} (~40% lower) and NO_2 from 36 to 44 (33% increase), then the NO_2 concentration at the street level increase by 6%. When O_3 is decreased from 61 to 42 µg m^{-3} and NO_2 reduced from 36 to 34 µg m^{-3} (using values from Brent Station) the NO_2 level decreases by about 11% due to lower NO_2 background concentration and lower O_3 background concentration resulting in less NO oxidation hence the lower total NO_2 concentrations. This study case shows that it is important to assess the influence of background stations when undertaking air quality assessment of streets. It is also important to test the performance to such changes and to choose background data can be shown to be representative of the overall background concentrations.

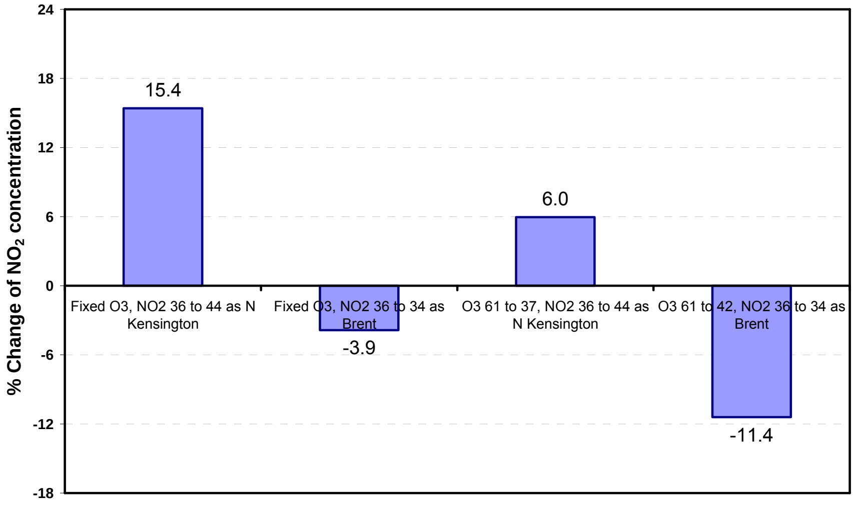

Figure 14: Percentage changes in concentrations based on changes of background concentrations (Base case BG Concentration of O_3 is 61 µg m^{-3} and NO_2 is 36 µg m^{-3})

When assessing the impact of traffic reduction measure it is advisable that the impact be calculated for the street increment and for the total air quality levels. For example, the case of reducing HDV volumes is illustrated. Figure 15 shows the comparison between percentage changes of NO_2 concentrations to the street increment and to the total concentrations of NO_2 resulting from changes in HDV volumes. Percentages reduction of NO_2 concentrations in the street increment is twice as high than the reduction achieved in the total levels (increment plus background). Therefore, although a particular traffic management option may result in a significant reduction in the street increment it may not have much of an influence in the total ambient levels. This will have implications for policy makers and city authorities in deciding which of the options are most effective locally and which require a more regional approach.

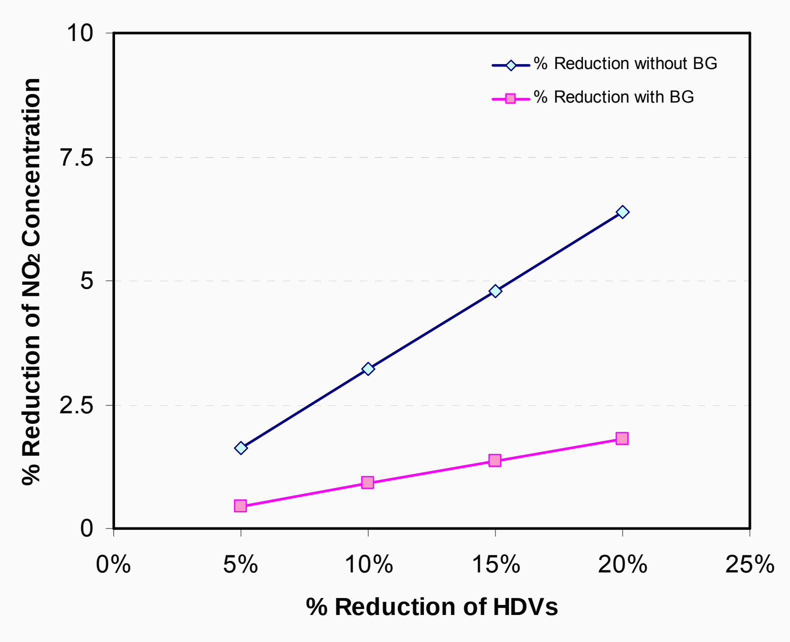

Figure 15: Percentage reduction of NO_2 concentrations due to reduction of HDVs; with and without background concentrations

iii) Traffic Contribution

It is often the case that local authorities implement general actions to reduce air traffic pollution but do not have detailed information available at hand. A particular area is the identification of the source group contributing to the major emissions. Such information would make the formulation and implementation of the control options more effective (Peace, et al., 2004). The example below illustrates the contribution of different traffic sectors to the overall street NO_2 levels.

Road traffic can be split into motorcycle, car, light goods vehicles, rigid and artic heavy goods vehicles, and buses. With OSCAR system, traffic contributions to emissions and air quality concentrations related to these traffic categories were calculated. Figure 16 depicts the contributions of car, LGV, rigid HGV, artic HGV and bus categories to annual mean NO_2 concentrations (calculated by CAR II) at Marylebone Road, year 2003. The major contributing source of NO_x emission and NO_2 is LDVs (approximately over 40%). This is because LDVs make up the highest proportion (about 90%) of fleet compositions at Marylebone Rd. However, taking into consideration the emission scenario examined in section 4, the study suggests that the reduction of HDVs is a more effective option than the reduction of car to public transport.

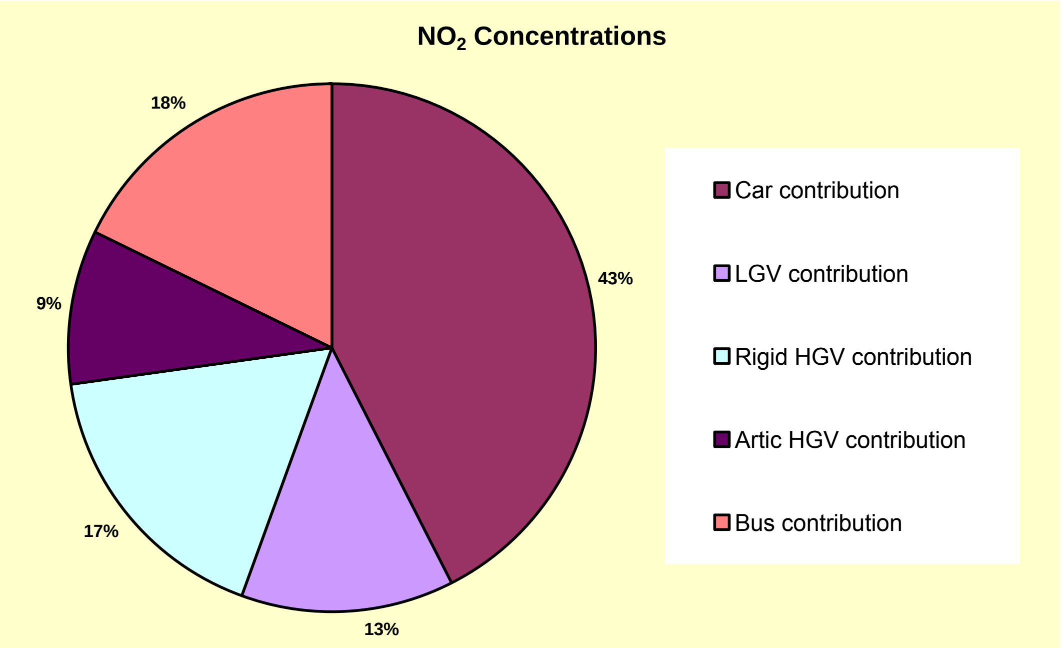

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Figure 16: Traffic contributions to annual average NO_2 concentrations at Marylebone Road (from Car II model results)

Figure 17 shows the contribution of traffic to annual mean PM_{10} concentrations predicted from CAR II. The levels of PM are influenced mostly by HDVs traffic. As a result of studies from the previous sections and traffic contributions, attention to HDVs is needed in order to control PM level. However, this does not suggest that the effects from LDVs should be ignored.

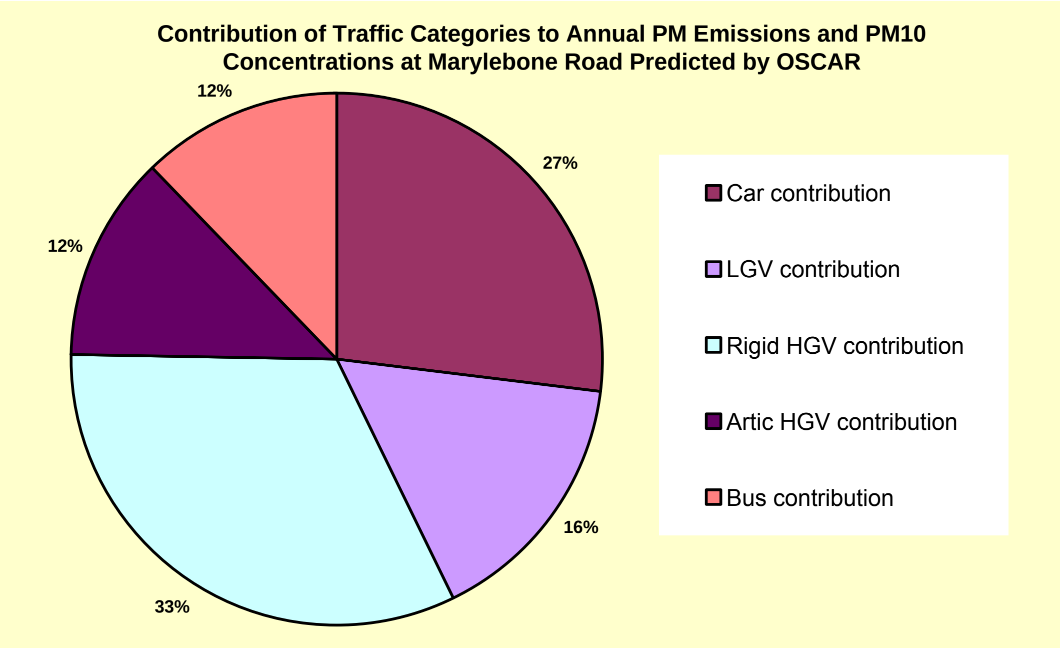

Figure 17: Traffic contributions to annual average PM emissions and annual average predicted PM_{10} concentrations by CAR II at Marylebone Road

5. Conclusion and discussion

5.1 Assessment of the case study

Overall emission scenarios studied with the OSCAR System and the summary of the results are included in Table 3. The predicted results from CAR II have highlighted the reduction on NO_x and NO_2 based on reduction of HDVs. Reduction of traffic speed tends to affect the reduction of PM_{10} the most. The impacts of emission scenarios on street pollution reduction, therefore, can be useful for local air quality management. The measures of pollution level reductions studied in this report has given the possibility of identifying the most effective way in related traffic pollution control. In practice, however, a combination of options may be more suitable and more acceptable to the city authorities, the road users and the public in general.

Although the percentage reductions from most measures examined in this report are approximately 10% more stringent strategies will obviously yield higher benefits in terms of air quality improvements. It is appreciated that the balance between the economic and social costs of emissions reductions for local authorities and the potentially substantial health benefits to the public is complex. However, as the study of Schrooten, et al. (2006) shows, such costs can be worthwhile for health benefit such increasing number of life years or reducing the number of premature deaths.

Table 3: Reduction of traffic related NO_x, NO_2, PM, and PM_{10} levels based on emission scenarios

Measures	5%	10%	15%	20%
NOx Emissions:				
1. Car to Bus	1.6	3.3	4.9	6.6
2. Reduction of HDVs	2.3	4.6	6.8	9.1
3. Reduction of traffic speed	1.8	3.6	5.1	6.6
PM Emissions:				
1. Car to Bus	1.1	2.2	3.2	4.3
2. Reduction of HDVs	2.8	5.7	8.6	11.4
3. Reduction of traffic speed	3.0	5.9	8.5	11.0
NO2 Concentrations:				
1. Car to Bus	1.2	2.4	3.6	4.8
2. Reduction of HDVs	1.6	3.2	4.8	6.4
3. Reduction of traffic speed	1.3	2.6	3.7	4.8
PM10 Concentrations:				
1. Car to Bus	1.1	2.2	3.2	4.3
2. Reduction of HDVs	2.8	5.7	8.6	11.4
3. Reduction of traffic speed	3.0	5.9	8.5	11.0

The study of the influence of the background concentrations has shown that it is important to understand the likely improvements resulting from traffic management options in the street increment and in the overall air quality. These type of studies can help the users to identify which pollutant sources play the major role for effectively controlling the total concentrations. In some cases, the reduction of local traffic emissions can be less important when the background concentrations and it may mean that a combination of local and regional strategies, working in an integrated way, are required to achieve the optimum improvements.

5.2 Recommendations resulting from the case study

It should be note that the methods used in this report are only specific examples to illustrate the methodology and the likely improvements. There still remain several measures that have not been studied in this report including improvement of technology used in vehicles which is expected to reduce related traffic emission in the UK and other European countries and eventually meet the EU emission standard (Peace, et al., 2004 and Schrooten, et al, 2006). In a comprehensive air quality management strategy a range of options will need to be considered.

The study does show how relatively simple tools can be employed respond quickly to questions on local air quality management issues. Most of the results shown in this report are based on annual averages of major traffic pollutant like NO_x and PM. More sophisticate models such as CAR FMI (also integrated into the OSCAR System) can be used to provide information with higher spatial and temporal resolutions. Such methods can help the users to understand the influence of more complex processes on local air quality. ..

5.3 Suitability for implementation in other cities

The models in OSCAR system used in this report have been evaluated and their use demonstrated as a tool for traffic management. The overall methodology, including the OSCAR System, can be easily adapted for other cities. .

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