LAEI 2008 Road Traffic Inventory Methodology Report

Environmental Research Group, King's College London

Prepared for the Greater London Authority and Transport for London

Authors: Emily Westmoreland, David Dajnak and Sean Beevers

Draft for comment

KING'S College LONDON

July 2010

Title	LAEI 2008 Road Traffic Inventory Methodology Report		
Customer	Greater London Authority and Transport for London (TfL)		

Environmental Research Group
King's College London
4th Floor
Franklin-Wilkins Building
150 Stamford St
London SE1 9NN
Tel 020 7848 4044
Fax 020 7848 4045

	Name	Signature	Date
Principal Authors	David Dajnak Emily Westmoreland		6 July 2010
Approved by	Sean Beevers		6 July 2010

CONTENTS

FIGURES

TABLES

1 Introduction

The London Atmospheric Emissions Inventory (LAEI) is a comprehensive database of geographically referenced emissions from all sources of air pollutants in and around the Greater London area. The newest release is the LAEI 2008 and supersedes the previous version of the inventory the LAEI 2006, released in October 2008.

The LAEI covers the entire Greater London Authority area as well as the area extending up to and including the M25 motorway (see Figure 1). This report describes the methodology used to estimate road transport emissions in 2003, 2004, 2006, 2008, 2011 and 2015.

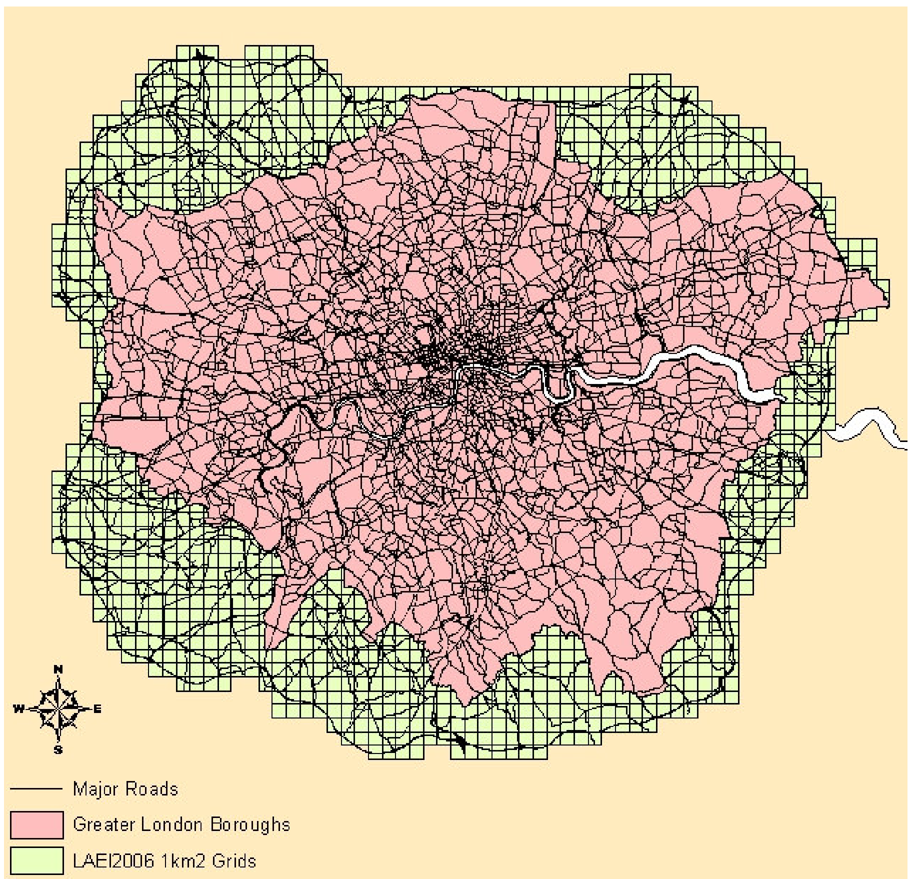

Figure 1: The extent of the LAEI 2008 illustrated by the 1km^2 grid cells.
(The Greater London Boroughs and all major roads in the area are superimposed on the top of the grid cells.)

1.1 Pollutants

Emissions for the following pollutants have been calculated:

- Benzene (C_6H_6)
- 1,3-Butadiene (C_4H_6)

- Carbon Dioxide (CO_2)
- Carbon Monoxide (CO)
- Non-Methane Volatile Organic Compounds or Hydrocarbons (NMVOC) [1]
- Oxides of Nitrogen (NO_X)
- Primary Nitrogen Dioxide (NO_2)
- Particles PM_{10} (Exhaust and Tyre and Brake wear);
- Particles $PM_{2.5}$ (Exhaust and Tyre and Brake wear);
- Sulphur Dioxide (SO_2)
- Methane (CH_4)
- Polycyclic Aromatic Hydrocarbons (PAH) (Benzo(a)pyrene)
- Nitrous Oxide (N_2O)

In addition, Petrol and Diesel fuel use has also been estimated.

Cold start $PM_{2.5}$ emissions have also been included in the LAEI, following the method used for PM_{10}.

1.2 Conventions

- All lengths are expressed in metres;
- All speeds are expressed in km hr^{-1};
- All link emissions are in g/km/s [2];
- All km^2 emissions are in tonnes/annum;
- Fuel use is expressed in litres of petrol or diesel.

1.3 Summary of updates for the LAEI 2008

The methodology used to create the traffic emissions for the LAEI 2008 has undergone significant changes compared with the LAEI2006 version and these include:

- A complete revision of the methods used to estimate traffic flow on the road network;
- A new set of emissions factors for all vehicle types, provided by Department for Transport;
- Revisions to the vehicle stock model, provided by AEA;
- An updated trip starts matrix used in estimating cold starts, provided by TfL;
- New London specific vehicle stock, also provided by TfL.

2 Updating London Traffic data

A completely new method has been developed by ERG to calculate the traffic flow on roads in London. The method was first used in the recent report to DEFRA, which compared

[1] Note – any reference to hydrocarbons excludes methane.
[2] g/km/s has been chosen as this represents the unit most likely to be used in dispersion models for road sources.

trends in emissions with measurements in London (Beevers et al, 2009[3]). The reasons for developing the new methods include:

- To incorporate the traffic information not only from the most recent year but for all years from 1999 to the present day through use of a smooth function applied to all data, road by road. This analysis goes some way to resolving uncertainties associated with traffic counts, which are taken infrequently;
- The traffic is generated for each hour of the year, prior to being summarised as an AADT equivalent value and thus transport strategies, affecting certain periods or times of the day, can be more appropriately assessed;
- The traffic data will ultimately lead to the development of hourly emissions estimates from road traffic and that this will in turn allow more appropriate comparisons with air pollution data and ultimately lead to a robust evaluation of the traffic emissions in London.

The following description of the methods used to generate traffic data is taken from the DEFRA report (Beevers et al, 2009):

The approach to develop an hourly emissions estimate for road traffic used a combination of data. The basis of the calculation was a 'London averaged' hourly traffic file based upon an average of Automatic Traffic Count (ATC) sites in central London, running between March 2003 and the end of 2008. The London average ATC data was assessed using GAM modelling techniques to estimate whether a long term trend existed in the data. The GAM modelling established that total hourly traffic counts could be described using smooth functions of hour of day, day of week, season and trend and that on average these factors could account for R^2 values ~ 0.9. Furthermore, there was no significant long-term trend, thus avoiding any problems associated with introducing an artificial trend into the data.

To calculate total traffic flows along individual roads the 'London averaged' data was scaled using manual count (MCC) data taken during weekday periods (7am to 7pm). Unlike the ATC data, manual counts are widespread and cover all of the major roads in London. This means that where a MCC count exists a specific hourly traffic file can be calculated. Since the manual count data is taken infrequently a number of tests were undertaken to compare col-located MCC and ATC data taken over the same 12 hour period as well as for longer periods of the year. Furthermore, since manual count measurements may be highly variable due to specific local events the time series of these data was smoothed using a LOESS smoothing function or where few measurements were taken an average of the data was used. Finally, when rescaling the ATC data care was taken to maintain daytime and night time differences in vehicle flow as well as weekend totals.

The MCC data are classified into 11 vehicle types and these were used to split the total vehicle counts for each hour of the day. Less data was available during weekday overnight periods, Saturdays and Sundays. Here a combination of datasets were used, including a set

[3] Beevers SD, Carslaw DC, Westmoreland E and Mittal H. 2009. Air pollution and emissions trends in London. Report produced for DEFRA by King's College London, Environmental Research Group and Leeds University, Institute for Transport studies

of MCC counts taken over a complete 24 hour period and Automatic Number Plate Recognition (ANPR) camera data. The former provided average proportions by vehicle type during the overnight minimum traffic periods and a combination of ANPR and weekday MCC data was used to apportion the weekend periods.

The results of the total vehicle counts was tested against a separate data set of ATC data recorded by DfT during 2006 and 2007 and not used in the model development. These tests were made for a combination of 16 site years and are presented as a predicted and measured profile, averaged over all sites and by day of the week (Figure 2). Alongside these results a summary of bias and the RMS error has also been presented (Table 1). Comparison of the predicted total (red), measured ATC total (blue) and the residual, (predicted-measured in light green) across an average of all sites show that the methods for creating vehicle totals are robust and provide good results across all days of the week.

The results in Table 1 show that over a 24 hour period very little bias exists in the predictions and in all cases is below 7%. Lack of data during weekends is apparent and as a consequence the method has the poorest performance during Saturdays. Because manual count data is specific to each site the 12 hour weekday periods should have the lowest uncertainty and for these separate results are presented. Here too modest bias estimates are apparent with average values of the order of -5%. Furthermore, Sunday, is well predicted for total vehicles and is widely understood to have small proportions of HGVs so is also a period where the traffic and emissions data is relatively robust. Overall the predicted average data has a RMS error of ~ ±10%.

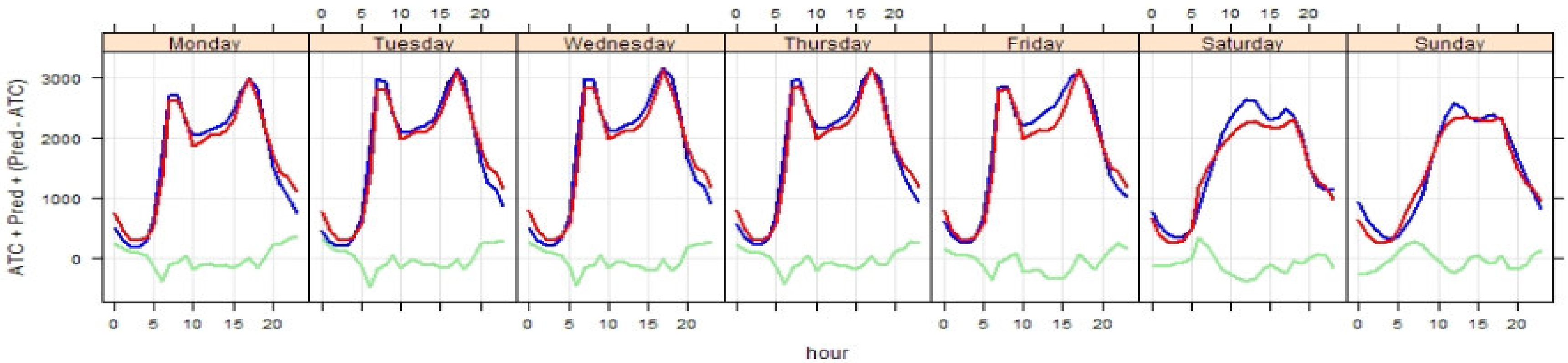

Figure 2. Comparison of predicted (red), measured (blue) and predicted-measured (light green) hourly total traffic flows. 16 site and year combinations for 2006 and 2007.

Table 1. Summary statistics from Figure 2

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	All days (RMS error)
Predicted	1659	1741	1753	1770	1753	1466	1419	
Measured	1657	1740	1773	1792	1820	1569	1461	**10.7%**
Bias (%) (pred-measured/meas)	**0.1%**	**0.1%**	**-1.1%**	**-1.2%**	**-3.6%**	**-6.6%**	**-2.9%**	(% of mean (measured))
Predicted (12 hrs)	2339	2455	2472	2495	2471	2066	2023	
Measured (12 hrs)	2438	2553	2588	2597	2625	2243	2036	**6.7%**
Bias (%)(pred-measured/meas)	**-4.1%**	**-3.9%**	**-4.5%**	**-3.9%**	**-5.8%**	**-7.9%**	**-0.6%**	(% of mean (measured))

This page is intentionally blank

2.1 Including vehicle km changes in London between 2003 and 2008

As a consequence of the new methods used to process the traffic data many of the changes associated with traffic interventions are inherent within the counts used in each of the years 2003, 2004, 2006 and 2008. Where they are not additional changes have been assumed such as those described for WEZ in section 6.3.

2.2 Vehicle kms travelled by road type

The vehicle kms travelled on minor roads have been re-calculated (
Table 2), based on the latest estimates provided by TfL[4] which in Greater London is estimated to be 31.19 billion vehicle km (bvkm) in 2008. Of this total, the vehicle km on major DfT and LTS roads have been calculated at 21.52 and 5.29 bvkm in 2008, respectively. This was calculated using the following equation[5]

Vehicle kms = (road traffic flow (24 hours) * 365 * (road link length (m) * multiplier)/1*10^{12}

Other changes include the number of DfT roads, which has increased compared to the LAEI 2006 as a result of around 400 LTS links being replaced with DfT counts. This partly explains an overall decline of ~15% in LTS vehicle kms in the Greater London Area for the LAEI 2008 compared with the LAEI 2006.

It should be noted that the TfL estimate of vehicle km for 2006 supersedes the figure of 31.15 bn used in the previous release of the LAEI. Indeed a direct comparison between the LAEI2008 and LAEI2006 shows that the vehicle km associated to minor roads has increased by about 20%.

Table 2: Vehicle km corrected for minor roads

Year	MINOR	TOTAL GLA
2003	5.44	32.47
2004	4.91	31.99
2006	4.71	31.78
2008	4.38	31.19

2.3 AADT comparisons

The vehicle kms travelled, by vehicle type, between 2003 and 2008 has been calculated and is displayed in Table 3. Note, Table 3 is concerned with the LAEI area and not the GLA area discussed in section 2.2.

[4] Charles Buckingham personal communication.

[5] Note: The road link length and multiplier is held within the traffic flow tables for each road link. Slip roads in this case are given a value of 0, dual carriageways and roundabouts a value of 0.5 and all other roads a value of 1. Note that some of the more complex road junctions may be assigned manually.

The results show that the total vehicle kms for all vehicle types (save motorcycles and cars) is greater than that of the LAEI 2006 (not shown), for example, the vehicle km of buses and LGVs has increased by 6% for the year 2006.

Table 3: Vehicle km (billion) for each vehicle type for the LAEI area (LAEI2008 version only).

LAEI Year	Motor cycles	Taxis	Cars	Buses	LGVs	Rigid HGVs	Artic HGVs	Total
2003	0.78	1.10	36.68	0.70	5.05	1.58	0.95	46.84
2004	0.76	1.09	36.11	0.70	5.05	1.56	0.95	46.22
2006	0.74	1.07	35.88	0.71	5.13	1.56	0.96	46.07
2008	0.73	1.06	35.43	0.71	5.09	1.59	0.97	45.58

2.4 Including taxis within London traffic data

Traffic count data for taxis are very limited; they are generally counted as cars. Some TfL manual classified data have separate counts for cars and taxis. These data have been used to calculate a revised set of proportions of taxis by area of London (Table 4). The zones within which these proportions are applied have also been changed to a single zone, which includes the WEZ and CZ area’s combined, the inner zone, which includes the IRR and an outer/external zone. The reason for a change to the central zone is that it better reflects the area where taxis operate (Figure 3).

Table 4: Proportion of taxis (taxis/(taxis+cars)) by area of London

Hour	Central	Inner	Outer/External
0	28.73	12.27	4.28
1	30.11	16.00	8.36
2	21.83	11.07	5.41
3	18.31	9.65	3.78
4	16.52	7.29	3.78
5	12.24	8.56	2.79
6	11.79	5.99	1.46
7	15.58	3.70	1.01
8	16.26	2.55	1.07
9	18.94	3.17	0.94
10	20.42	4.80	1.33
11	21.55	4.83	1.83
12	19.20	4.89	1.59
13	20.95	5.00	1.59
14	26.61	5.60	1.84
15	21.97	4.34	1.61
16	21.70	4.79	1.72
17	20.70	4.51	1.63
18	19.98	4.24	1.33
19	20.47	5.17	1.63
20	22.69	7.00	2.03
21	24.96	7.23	2.29
22	25.92	7.04	2.17
23	29.18	8.74	2.67

Figure 3 An estimate of taxi operation in London using GPS vehicle tracking (taken from the LAEI 2001)

3 Vehicle Speed Data

Vehicle speeds on the major road network have been updated using an average of all traffic speed data taken by the TfL floating car from 2003 to 2008. These measurements cover the entire major road network with additional measurements being taken in inner and central London (Figure 4). These speeds separately consider three intervals throughout the day (am, inter-peak and pm), with the CCS speed survey covering six periods of the day in the CCS area and four periods in Inner London. Overnight speeds are also taken periodically and all speed data has been carefully matched with the road network. Speeds in the area outside the Greater London boundary have also been updated. Minor road vehicle speeds have been kept the same as in LAEI 2006 and are as follows: central and IRR = 18.1 km h^{-1}, inner = 25 to 30 km h^{-1} and outer = 30 to 35 km h^{-1}.

Figure 5 and Figure 6 illustrate the comparison of speeds used in the LAEI2006 and the LAEI2008. It can be seen that on the whole there is good agreement between the two LAEI versions, suggesting that speed has changed little over time. There is however a pronounced region of discrepancy in speeds on the DfT referenced links and further analysis of these speeds (Figure 7) illustrates that this is concentrated in the external zone of the LAEI area. Further investigation revealed that the links in question have not had a speed update for a number of years and that the speeds were not based on site-specific data but instead set to an average speed for the external zone. Since the new speeds are based on site-specific data this update is considered an improvement to the LAEI.

Figure 4 The CCS speed network used in compiling central and inner London speeds

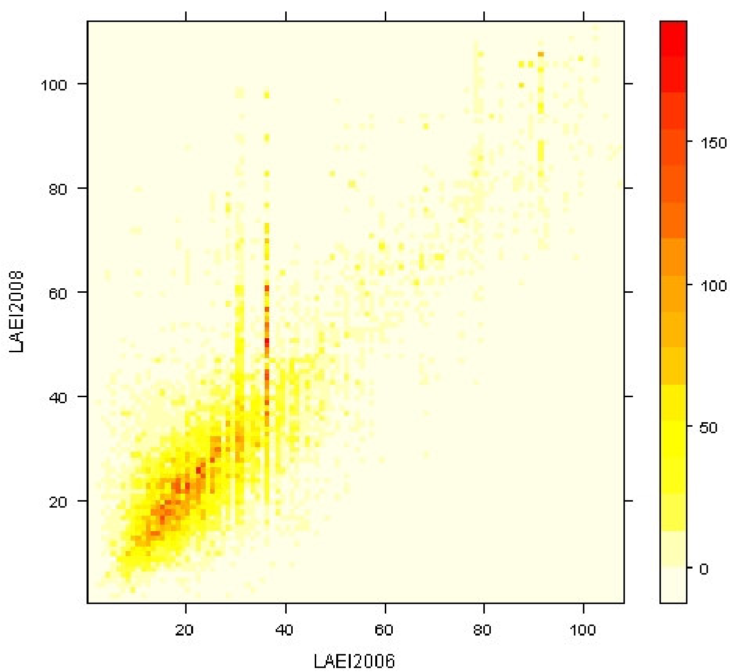

Figure 5 Comparison of hourly speed for DfT referenced links between the LAEI2006 and the LAEI2008.

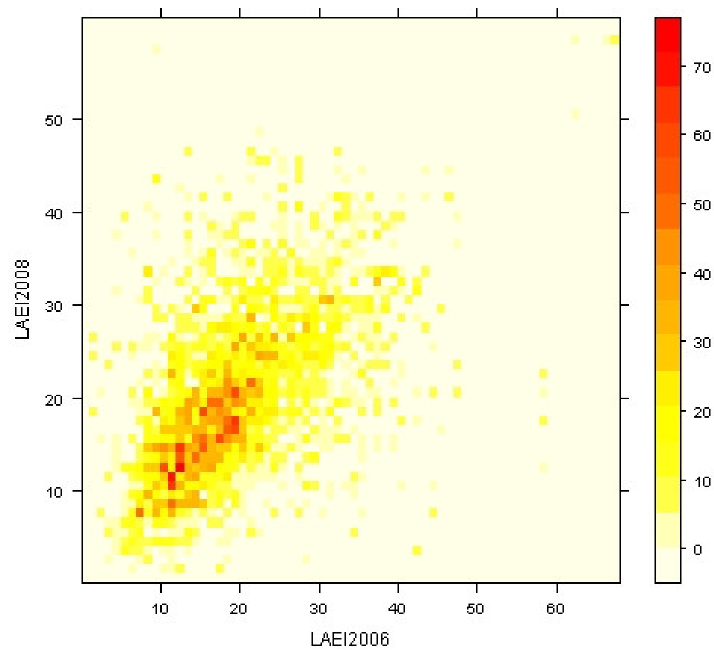

Figure 6 Comparison of hourly speed for LTS referenced links between the LAEI2006 and the LAEI2008.

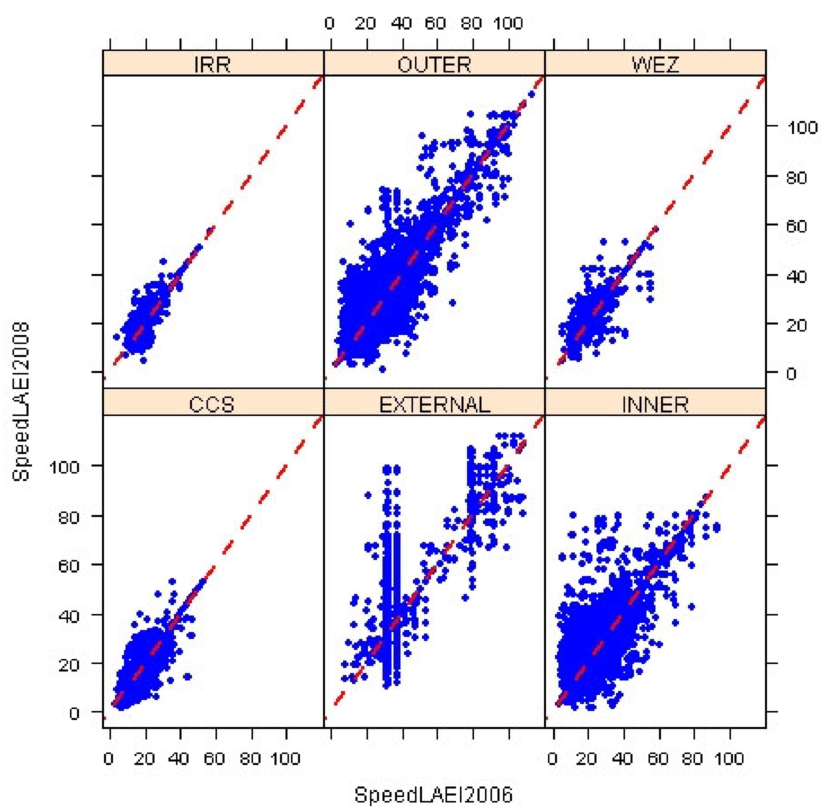

Figure 7 Comparison of hourly speed for DfT referenced links split by location between the LAEI2006 and the LAEI2008.

4 Vehicle Stock Data

4.1 Changes to the national stock model

The vehicle stock in London has been updated since the LAEI 2006 and is based on the UK National Atmospheric Emissions Inventory (NAEI) fleet composition data[6]. One of the most significant of these changes is the proportion of failed catalysts in petrol cars, which has increased by about 12% up to 2008. The consequence of this change is that the proportion of pre Euro equivalent vehicles within the fleet has increased significantly and has increased the emissions of all pollutants from cars. This effect is short lived and after 2009 the catalyst failure rate returns to a very low level, 5% in 2009 and 2% by 2015. The proportion of failed catalysts in petrol LGV's has also increased by about 15% up to 2008, but unlike cars, LGV catalyst failure rates remain at about 11% from 2009 to 2025.

4.2 Changes made to taxi stock information

Taxi stock has been updated based on information from the Public Carriage Office (PCO) for 2003, 2004, 2006, 2008, 2011 and 2015[7] (Table 5). Stock estimates up to and including 2008 are based on the actual fleet, whereas the 2011 to 2015 information is based on forecast data, which reflects the GLA's taxi strategy. Additionally, it has been assumed that 7.5% of retro-fitted taxis (Euro 3 equivalent) fail and so for the years 2008, 2011 and 2015 the taxi stock has been readjusted to reflect this[8].

Table 5: Taxi Stock data (%) for the years 2004, 2006, 2008, 2011 and 2015

Euro Class	2003	2004	2006	2008	2011	2015
Pre Euro	16	12	4	4.5	2.8	1.3
Euro 1	48	42	21	0.7	-	-
Euro 2	26	26	12	3.2	-	-
Euro 3	11	19	60	70.1	58.2	38.1
Euro 4	-	-	2	20.4	38	39.3
Euro 5	-	-	-	-	-	16.2
Euro 6	-	-	-	-	-	4.1
LPG	-	1	1	1	1	1

4.3 Estimates of LT Buses stock

The LT bus stock has also been revised according to the latest information[9] (Table 6). In common with Taxi's, bus stock up to 2008 is based on the actual fleet, whereas the 2011 to 2015 information is based on forecast data[10].

[6] Personal communication with Tim Murrells at AEAT; NAEI Department for Transport (DfT) forecast dated April 2008.
[7] Personal communication with Finn Coyle at TfL.
[8] TfL personal communication. Claire and Yvonne Brown (Feb 4th 2010)
[9] Personal communication with Finn Coyle at TfL.

Table 6: TfL Bus Stock data (%) for the years 2004, 2006, 2010, 2015, 2020 and 2025[11]

Euro Class	2003	2004	2006	2008	2011	2015
Pre-Euro	15	7	-	-	-	-
Euro 1	2	1	-	-	-	-
Euro 2	20	6	-	-	-	-
Euro 2 + CAT[a]	1	1	-	-	-	-
Euro 2 + Trap	24	36	37	31	13.5	-
Euro 2 + Trap + SCR[b]	-	0.1	-	-	-	-
Euro 3 + Trap	37	48	60	56	53.6	41.8
Euro 3 + Trap + SCR	-	0.1	-	-	-	-
Euro 4	-	-	2	12	21.4	21.4
Euro 5	-	-	-	1	8.4	33.7
E4 Hybrid	-	0.03	0.1	0.4	1.9	1.9
E5 Hybrid	-	-			1.2	1.2

a: Oxidation Catalyst; b: Selective Catalytic Reduction

5 Emission Factors

5.1 Assumptions and Data

A complete revision of the emissions factors, available from DfT and compiled by TRL, were used in the calculation of traffic emissions in the LAEI 2008. The emissions factors follow a similar format to previous versions in that they use polynomial expressions to express emissions in g km^{-1} vs. vehicle speed, for different pollutant types[12]. However, the number of vehicle types has increased due in the main to the disaggregation of vehicle size or weight. A more detailed note of the headline changes due to the adoption of the new vehicle stock and emissions factors will be given as part of the MAQS 2 work currently being undertaken by King's, however some notable changes to NO_X and PM_{10} based on the year 2006 are summarised below and in Table 7:

- Total PM_{10} emissions are 12 % lower
- Total NO_X emissions are 10% higher (NO_2 16% higher)
- The largest changes from new emission factors are for buses, which have more than 60% higher NO_X, NO_2 and PM_{10} emissions. Emissions from HGVs, on the other hand, are lower for all pollutants e.g. NO_X emissions for articulated HGVs have fallen by 14%.
- Emissions from cars have not changed significantly and although motorcycle emissions show some large changes, they contribute only a small proportion of total vehicle emissions.

---

[10] Revised 2011 and 2015 as part of MAQS 2
[11] Source: TfL buses.
[12] See http://www.naei.org.uk/emissions/index.php for details.

- As a consequence of the changes across vehicle types, there is substantial spatial variation across London. These largely depend on the varying proportions of different vehicle types in different areas of the city. For example, the increase in taxi and bus emissions is more important for central London than outer London where the decrease in HGV emissions has more impact.

Table 7: Emission factors sensitivity of new DfT emission factors. (Percentage change compared to old emission factors) – Year 2006

Pollutant	MC	Taxis	Cars	Buses	LGV	Rigid	Artic	Total
CO_2	0%	11%	-2%	28%	-21%	-29%	-5%	-5%
Exhaust PM_{10}	-54%	29%	-5%	65%	-17%	-11%	-32%	-12%
NO_X	32%	41%	6%	63%	0%	0%	-14%	10%
NO_2	32%	22%	3%	60%	-2%	0%	-14%	16%

5.2 Cold start emissions

The effect of cold starts is included as an additional emission dependent on the number of trips a vehicle makes and the mean length of each trip. The methodology used in the LAEI is the same as in the COPERT IV methodology. (For more details, see http://lat.eng.auth.gr/copert/)

Cold start emissions have been calculated using revised data from a recent LTS model forecast. This has made a large change in the number of total trip starts within the LAEI, an increase of around a factor of 4. The cold start emissions are calculated for cars and LGVs for CO, NMVOCs, NO_X and PM_{10} on a km^2 basis and are expressed in terms of annual emission rates.

$PM_{2.5}$ emissions from cold starts have also been included and these are based on the assumption that approximately 90% of the PM_{10} cold start emissions are emitted as $PM_{2.5}$.

However the change in actual cold start emissions is a combination of both the change in trip starts and the new emission factors and have resulted in the following emissions changes:

CO cold start emissions have increased by ~12 times.
Emission factors for CO have changed substantially and in combination with the factor of 4 increase in trips starts has increased CO significantly.

PM_{10} cold start emissions have decreased by ~20%
The PM_{10} emission factors for both pre Euro and Euro 1 cars are lower than previously assumed. Therefore the reduction in g km^{-1} released by pre Euro vehicles will go some way to explain the overall reduction in cold start PM_{10} emissions. A similar effect is seen for pre Euro and Euro 1 LGVs.

NO_X cold start emissions have increased by ~2.4 times.
The combination of a change in NO_X emission factors alongside the increase in trip starts has contributed to the increase in cold start emissions, although the increase is smaller than would have been the case using the new trip start data alone.

NMVOC cold start emissions have increased by ~12 times
The new DfT emission factors for NMVOC for all types of petrol cars and LGVs are greater than previously assumed. This increase, alongside the increase in trip starts has lead to an overall increase in coldstart NMVOC emissions and is similar to CO.

5.3 Evaporative Emissions

Evaporative emissions of NMVOCs for petrol vehicles arise from a number of different sources. The methodology that has been used in their calculation is consistent with the COPERT IV methodologies. The three principal sources of emissions are diurnal losses, hot soak losses and running losses. Diurnal losses arise because of changes in temperature throughout each day through “tank breathing”. Hot soak losses arise when evaporation occurs from the fuel delivery system when a vehicle is stationary but with a hot engine. Finally, running losses are those that occur when a vehicle is in motion. The calculations take account of fuel volatility, changes in ambient temperature and the vehicle technology used to control such losses. The change in trip start data has also affected the evaporative emissions and since the methods used have not changed the emissions of NMVOC and Benzene from this source has increased considerably.

6 Assumptions for the 2011 and 2015 emissions inventories

This section provides details of the assumptions that have been used in the calculation of emissions for forecast years 2011 and 2015 in the LAEI 2008.

6.1 Vehicle km and speed changes for 2011 and 2015

Forecast traffic changes were provided by TfL beyond 2008 and were consistent with the TfL Business Plan. The business plan assumes that between 2006 and 2026 average traffic growth is 0.36% per year and this change was applied to the 2008 traffic data by location and time of day (Table 8). To account for changes in speed for future years, speed reduction was assumed to be in the same proportion as the growth in traffic (Table 9).

Table 8: Growth factors, expressed as a % change between 2008 and the forecast year, by period and location

Peak Periods	Location	2011	2015
AM	central	0.95	2.22
AM	inner	0.95	2.22
AM	outer	0.98	2.28
AM	external	0.97	2.26
INTER	central	1.17	2.74
INTER	inner	1.16	2.70
INTER	outer	1.15	2.67
INTER	external	1.15	2.68
PM	central	1.28	2.99
PM	inner	1.09	2.55
PM	outer	1.08	2.53
PM	external	1.09	2.55
Overnight	central	1.15	2.68
Overnight	inner	1.09	2.54
Overnight	outer	1.08	2.52
Overnight	external	1.09	2.53

Table 9: Speed change post 2008: a 1% change in total flow leads to a 1% change in speed

Peak Periods	Location	Speed change (%)
AM	Central	1
AM	Inner	1
AM	Outer	0.9
AM	External	0.9
INTER and 7.00 pm to 10.00 pm	Central	1
INTER and 7.00 pm to 10.00 pm	Inner	0.9
INTER and 7.00 pm to 10.00 pm	Outer	0.7
INTER and 7.00 pm to 10.00 pm	External	0.7
PM	Central	1
PM	Inner	1
PM	Outer	0.8
PM	External	0.8
Overnight	All location	No change

6.2 The effect of the LEZ on vehicle stock between 2008 and 2015

The effect of the LEZ phase 1, 2 and 4 has been applied to HGVs and coach vehicle stock projections, using part 5 of the LEZ impacts analysis work[13]. The LEZ phase 3 and the impact of the recession have been applied to LGV diesel stock as with the latest MAQS.

The LEZ affects the composition of HGVs, coaches, heavier diesel LGVs and minibuses and the assumptions for these vehicle types are given in Table 10 to Table 13.

Table 10 LEZ Articulated HGV stock composition (%)

Euro class	Articulated HGV		
	2008	2011	2015
Pre Euro	0	0	0
Euro 1	0.3	0	0
Euro 2	4.5	0.2	0
Euro 2 + Trap	1.7	1.1	0
Euro 3	55.3	26.9	0
Euro 3 (PM) + Euro2 (NO_X)	2.8	0.8	0
Euro 4 (PM) + Euro3 (NO_X)	0	0	7.2
Euro 4	32.3	30.2	7.9
Euro 5	3.0	40.8	50.5
Euro 6	0	0	34.5

Table 11 LEZ Rigid HGV stock composition (%)

Euro class	Rigid HGV		
	2008	2011	2015
Pre Euro	0	0	0
Euro 1	1.1	0	0
Euro 2	7.0	0.6	0
Euro 2 + Trap	1.8	0.9	0
Euro 3	57.3	36.0	0
Euro 3 (PM) + Euro2 (NO_X)	3.9	1.2	0
Euro 4 (PM) + Euro3 (NO_X)	0	0	7.4
Euro 4	26.0	22.4	6.4
Euro 5	2.9	38.9	53.8
Euro 6	0	0	32.4

[13] Air Pollution Modelling of the London Low Emission Zone, (Phase 5 update), November 2006.

Table 12 LEZ Coach stock composition (%)

	2008	2011	2015
Pre Euro	1.1	0.0	0
Euro 1	1.4	0.1	0
Euro 2	9.0	0.7	0
Euro 2 + Trap	5.7	6.1	0
Euro 4 (PM) + Euro 2 + Trap (NO_X)	0	0	2.4
Euro 3	48.9	35.8	0
Euro 3 (PM) + Euro2 (NO_X)	5.9	2.2	0
Euro 4 (PM) + Euro3 (NO_X)	0	0	14.6
Euro 4	25.4	23.0	16.6
Euro 5	2.7	32.2	40.8
Euro 6	0	0	25.5

Table 13 LEZ diesel LGVs and minibus stock composition (%)

Euro class	Diesel LGVs and Minibuses	
	2011	2015
Pre Euro	1.2	0
Euro 1	3.1	0
Euro 2	6.5	0.1
Euro 2 + rpc	1	0.3
Euro 3	44.8	17.4
Euro 4	40.5	22.2
Euro 5	2.9	59.9
Euro 6	0	0

6.3 WEZ assumptions

2008

Since the major roads contained within the LAEI 2008 use traffic data up to and including traffic counts in 2008, the impact of changes to traffic strategies such as WEZ are implicit within these data. However, for the major roads not updated since the WEZ introduction in February 2007 and for LTS and minor roads the following WEZ changes, provided by TfL, have been applied. These are summarised in Table 14.

Table 14 Western Extension traffic change during charging hours (07.00am to 06.00 pm)

Vehicle Type	MC	Taxis	Cars	Buses	LGV	HGV
Traffic change	-1.31%	-7.05%	-26.34%	+4.52%	-12.93%	+2.81

2011 and 2015

For the years 2011 and 2015 the WEZ is assumed to be removed. The removal was achieved by applying a set of factors provided in Table 15 to both traffic flow and speed for the appropriate hours charging hours[14].

Table 15: Western Extension traffic change during charging hours (07.00am to 06.00 pm)

	Calculated 50% Capacity Return % Change					
Location	**Cars**	**LGV**	**HGV**	**Taxis**	**Buses**	**Speed**
CCS	-0.4	-2.9	-6.2	5.0	-0.4	2%
Inside Free Area	8.7	-13.6	-11.6	2.2	-2.3	-2%
Inside WEZ	27.3	13.2	0.0	5.0	-3.5	-5%
Eastern Boundary	3.7	1.8	-2.5	-5.5	-0.6	1
Western Boundary	-1.7	-4.7	-9.3	0.4	-4.9	1
Inner	2.3	0.3	-0.8	1.6	-0.4	0
NSC	0.8	0.2	0.3	1.0	-0.2	0
Outer	0.8	0.0	-0.4	2.3	-0.1	0

6.4 Particle traps, SCR and other emissions control assumptions

Within the LEZ scenarios used in the LAEI, vehicles that fit particle traps are commonplace. The assumptions used to factor Euro class vehicle emissions to simulate the introduction of such particle traps are given in Table 16. In addition a 50% reduction in NO_X has also been assumed for buses using a combination of exhaust gas recirculation (EGR) and selective catalytic reduction (SCR). Finally, the assumption for Hybrid buses is that they have 30% less CO_2 and 20% less NO_X emissions than a standard Euro 4 bus.

Table 16 Particle trap assumptions for pollutant emissions

NO_X	PM_{10}[15]	CO	HC[16]	SO_2	CO_2
0.95	0.05	0.1	0.1	1.008	1.008

7 Estimating uncertainty in LAEI emissions

Previous versions of the LAEI have been accompanied by a comprehensive estimate of vehicle emissions uncertainty. This resulted in typical values for PM_{10} exhaust, NO_X, CO and

[14] TfL personal communication
[15] Also applied to PaH and $PM_{2.5}$
[16] Also applied to CH_4, Benzene and 1-3 Butadiene

NMVOC of 22 to 27% (2σ). However, a key component of the uncertainty estimate was the uncertainty associated with the emissions factors, by vehicle type. As described above these have change considerably since the LAEI 2006 and so it may not be reasonable to assume a similar level of uncertainty in the new factors. Estimates of uncertainty cannot be undertaken using the information provided with the new emission factors and it is not possible therefore to calculate the uncertainty of the emissions for the LAEI 2008.

It is recommended that estimates of uncertainty for each of the emissions factors be established for future versions of the inventory.

Acknowledgements

The authors would like to acknowledge the assistance of Martin Obee (TfL) for the DfT traffic counts, continuous traffic data and vehicle speed data, Tim Murrells for his assistance with national fleet statistics, Finn Coyle (LT Buses) for a description of the London bus fleet and taxi stock information, Mark Powell of MVA for provision of CCS traffic counts and speeds, Mike Rowland for TfL speed data and Charles Buckingham (TfL) for traffic projects and trip start data. Finally the authors would like to thank both the GLA and TfL for their support for this work.