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Emissions inventory methodology for the LestAir study

LestAir Technical Paper 2

Report for Leicester City Council

Ricardo-AEA/R/ED58496
Issue Number 1
Date 23/10/2013

Customer:

Leicester City Council

Customer reference:

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Ricardo-AEA reference:

Ref: ED58496- Issue Number 1

Contact:

Guy Hitchcock
Ricardo-AEA Ltd
Gemini Building, Harwell, Didcot, OX11 0QR
t: 01235 75 3327
e: guy.hitchcock@ricardo-aea.com
Ricardo-AEA is certificated to ISO9001 and ISO14001

Author:

John Abbott

Approved By:

Guy Hitchcock

Date:

23 October 2013

Signed:

1 Introduction

Leicester has had an Air Quality Management Area (AQMA) in place since 2000. The AQMA covers about 3% of Leicester's population, many of whom are amongst the most deprived of the city's residents. Nonetheless, annual mean nitrogen dioxide (NO_2) concentrations exceed the European Union Limit Value in a substantial part of the city. There is little evidence of a robust downward trend in levels; in fact in recent years the situation has deteriorated in some areas.

Although the AQMA has been declared on the basis of NO_2, both NO_2 and PM_{10} are of concern. While the daily and annual mean PM_{10} limit values were achieved at all sites in 2011, at two sites only a small margin remained for achieving the daily objective. In addition, there is a growing preoccupation with the health impacts of $PM_{2.5}$. Annual average nitrogen dioxide concentrations exceeded the limit value at fiver sites in 2011. Road traffic is a major contributor to nitrogen dioxide and particulate matter concentrations in Leicester.

The Council's current statutory Air Quality Action Plan (AQAP) is proving insufficient to achieve the requisite amount of improvement: The LestAir project, therefore, will be a key element of the process in identifying and implementing further measures that will result in reductions in local air pollution emissions across the main NO2 and PM emissions sectors in the AQMA. In particular it will investigate options for an LEZ, whether enforced through regulation or sectoral agreements. This report describes a methodology for assessing the impact of LEZ measures on pollutant emissions and on measured pollutant concentrations.

Section 2 of the report describes how the emissions of oxides of nitrogen, particulate matter (PM_{10} and $PM_{2.5}$) and carbon dioxide from road transport were calculated for specific parts of the AQMA. It presents the results for some example scenarios.

Section 3 of the report describes how the proportions of oxides of nitrogen emissions, primary nitrogen dioxide emissions and measured nitrogen dioxide concentrations can be attributed to different classes of vehicle. The results of this source apportionment are presented for the current year (2011). A similar method can be used to forecast concentrations at monitoring sites. The method is applied to forecast 2016 concentrations for some example scenarios.

2 Road transport emissions methodology

2.1 Introduction

This section describes how the annual emissions of pollutants from road transport were estimated. In principle, the annual emissions from a single road link were estimated from:

$E = 365.AADT.EF.L$

where

E is the annual emission of pollutant, g year^{-1}

365 is the number of days in a year, day year^{-1}

AADT is the annual average daily traffic flow, vehicles day^{-1}

EF is an emission factor, g (vehicle-km)$^{-1}$

L is the length of the road link

The total emission from a network of roads is the sum of the emissions from the road links in the network.

The emission factor, EF, depends on:

- the pollutant
- vehicle speed
- the composition of the vehicle fleet

This section describes:

- the specification of the road network
- the estimation of AADT traffic flows on each road link
- the estimation of vehicle speeds on each road link
- the estimation of the traffic composition on each road link
- the calculation of emission factors
- the calculation of aggregate emissions over the road network or parts of the network.

2.2 Traffic data sources

The road transport emission inventory was based on outputs from the Leicester and Leicestershire Integrated Transport Model (LLITM) provided by Leicester City Council. LLITM is an integrated transport and land use model successfully used by Leicestershire County Council, Leicester City, developers, and other external parties, to appraise land use changes, transport schemes and strategies and to secure funding.

The LLITM model output provided morning peak (08:00-09:00) and afternoon peak (17:00-18:00) weekday traffic flows for road links throughout the Leicester area. Each road link was specified by the Ordnance Survey coordinates of its start and end nodes. Leicester City Council provided LLITM outputs for the 2008 base case and the 2016 do-nothing case.

This study considers road links with mid-points within the rectangular area with Ordnance Survey eastings in the range 454,000-464,000 m and northings in the range 299,000 and 309,000 m. Special consideration was given to road links with midpoints within the Leicester

Air Quality Management Area (AQMA). The AQMA was additionally subdivided into 15 areas in order to discriminate between measures applied in different parts of the city. Fig. 1 shows the LLITM road network included in this study and the AQMA. Fig. 2 shows the AQMA subdivisions, with indicative names for each part of the AQMA.

The Department for Transport provided classified manual traffic counts for selected major road links in Leicester[1]. Fig. 1 shows the sites of the count points. The traffic counts give annual average traffic flows by direction for the following vehicle types:

- 2-wheeled Motor Vehicles
- Cars & Taxis
- Buses & Coaches
- Light Goods Vehicles
- 2-Axle Rigid HGV
- 3-Axle Rigid HGV
- 4- or 5-Axle Rigid HGV
- 3- or 4-Axle Artic HGV
- 5-Axle Artic HGV
- 6- or More Axle Artic HGV
- All HGVs
- All Motor vehicles

This study used traffic count data for 2008 and 2011.

Leicester City Council provided traffic speed data derived from the TrafficMaster GPS tracking system. The data set provided morning and afternoon peak speeds in 2012 for those road links in Leicester with an adequate sample of vehicles equipped with TrafficMaster. Fig.3 shows the road links included in the TrafficMaster data set. It also shows the LLITM network for comparison. The TrafficMaster data set covers the major roads, but does not include many of the minor roads

[1] http://www.dft.gov.uk/traffic-counts/download.php

Fig. 1: Selected LLITM road network

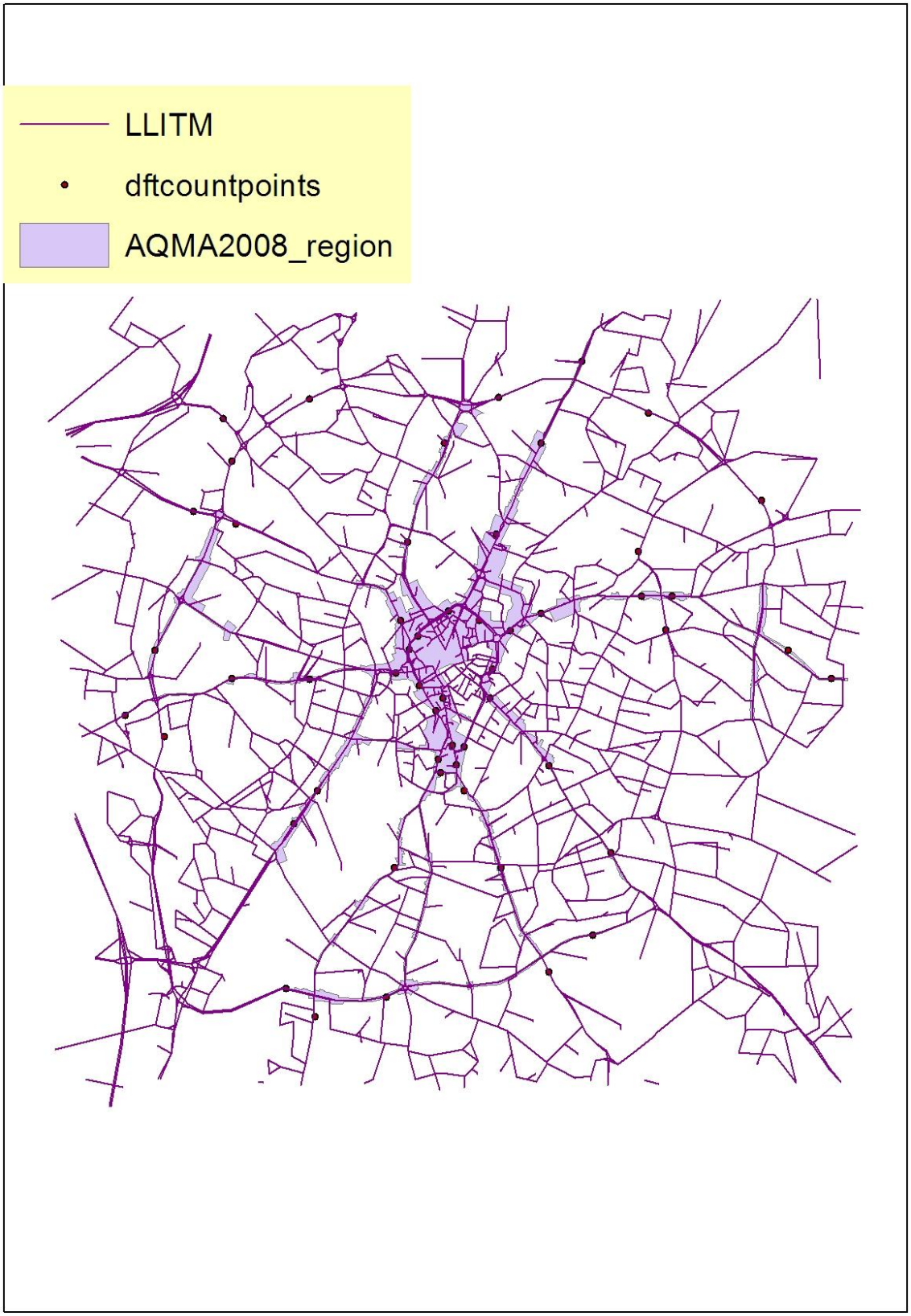
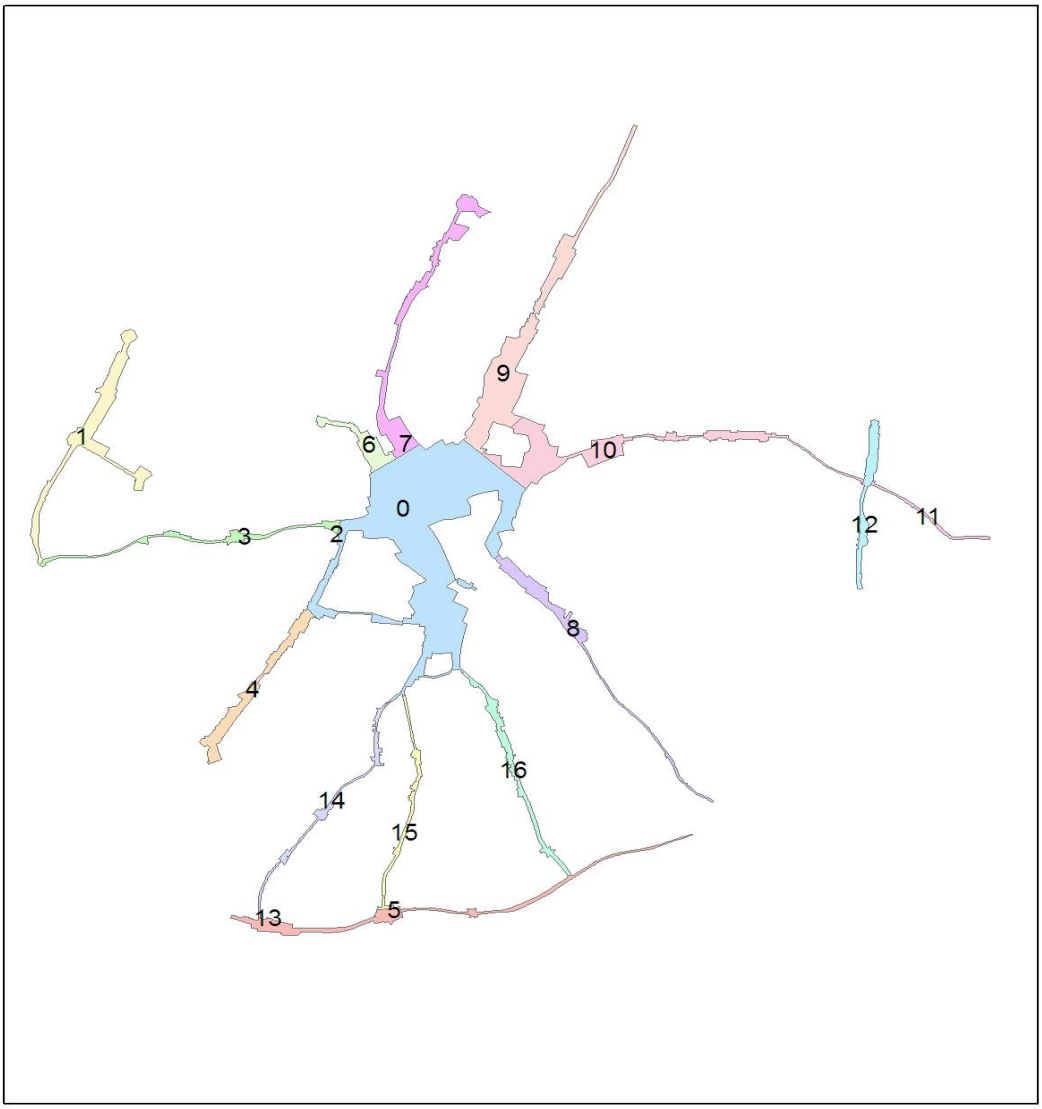
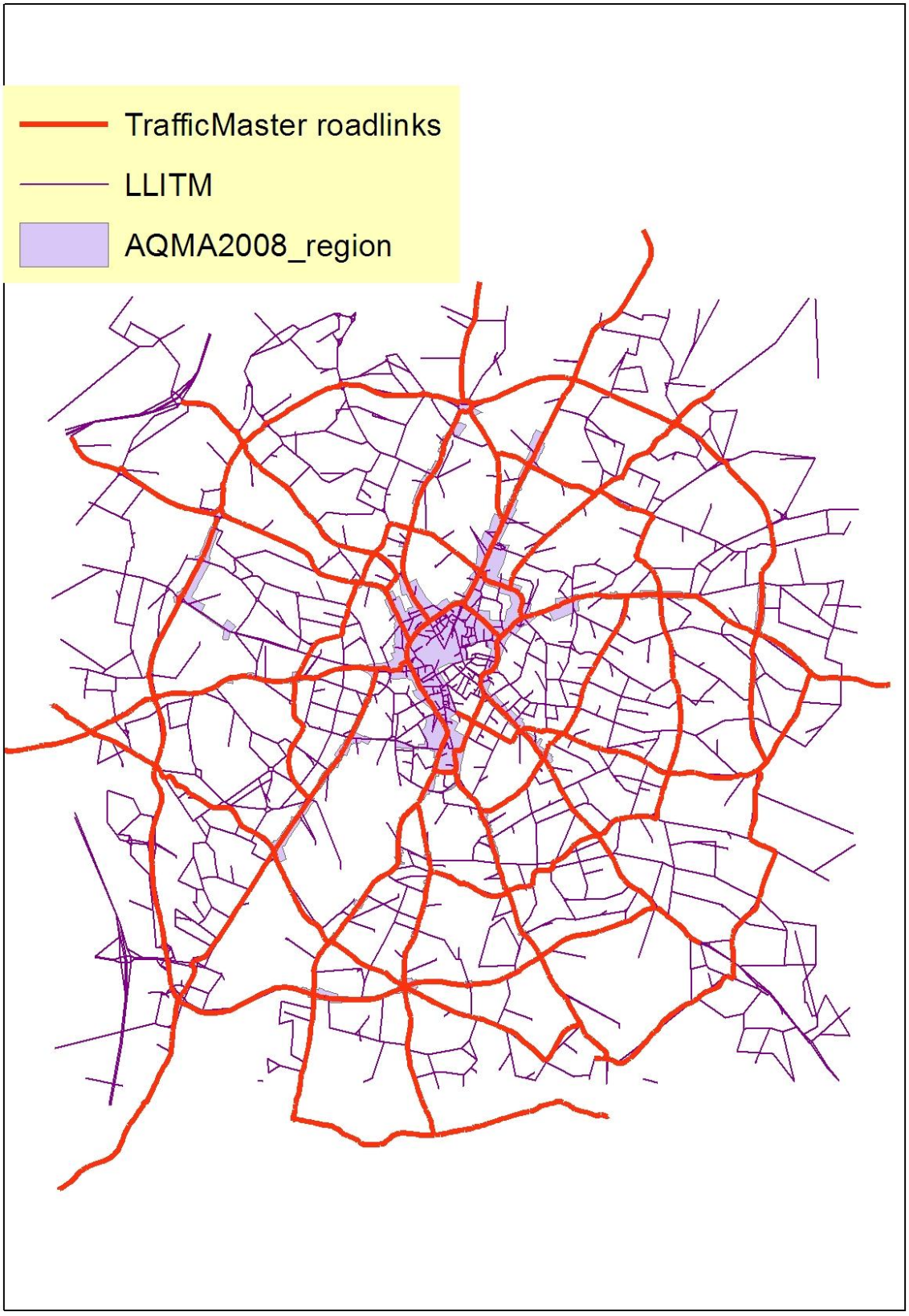


Fig 2: Subdivision of the AQMA



0	Central	9	Melton Road
1	New Parks Way	10	Humberstone Road
3	Hinckley Road	11	Uppingham Road
4	Narborough Road	12	Goodwood Road
5	Asquith Way	14	Aylestone Road
6	Groby Road	15	Saffron Lane
7	Devonshire Road	16	Welford Road
8	London Road	2&13	Unassigned

Fig. 3: TrafficMaster data set road network



2.3 Scaling the LLITM traffic flows

The LLITM data set provided morning and afternoon peak weekday traffic flows for 2008 and 2016. The preparation of the emission inventory requires estimates of annual average daily traffic flows for the inventory base year (2011) and the future year (2016). The methodology assumes that:

- annual average daily traffic flows for 2008 can be estimated from the sum of the morning and afternoon peak LLITM flows using a simple scaling factor
- AADT traffic flows for 2011 can be estimated from 2008 AADT flows and hence from the 2008 peak LLITM flows using a simple scaling factor
- annual average daily traffic flows for 2016 can be estimated from the sum of the 2016 morning and afternoon peak LLITM flows using the 2008 scaling factor

The scaling factors were derived by comparing the LLITM flows with the DfT traffic counts. The most appropriate LLITM links were selected for each count point. Care was taken to ensure that the selected roads corresponded to:

- the same road link
- the same direction
- the entire flow (e.g there were no slip roads running parallel to the selected link)

Fig. 4 shows the 2008 AADT flows plotted against the sum of the 2008 morning and afternoon peak LLITM flows. The slope of a least squares straight line through the origin is 6.3982. This scaling factor was used to estimate 2016 AADT flows from the 2016 LLITM data set.

Fig. 5 shows the 2011 AADT flows plotted against the sum of the 2008 morning and afternoon peak LLITM flows. The slope of a least squares straight line through the origin is 6.350. This scaling factor was used to estimate 2011 AADT flows from the 2008 LLITM data set.

Fig. 4: Scatter plot of 2008 AADT flows against 2008 LLITM peak flows

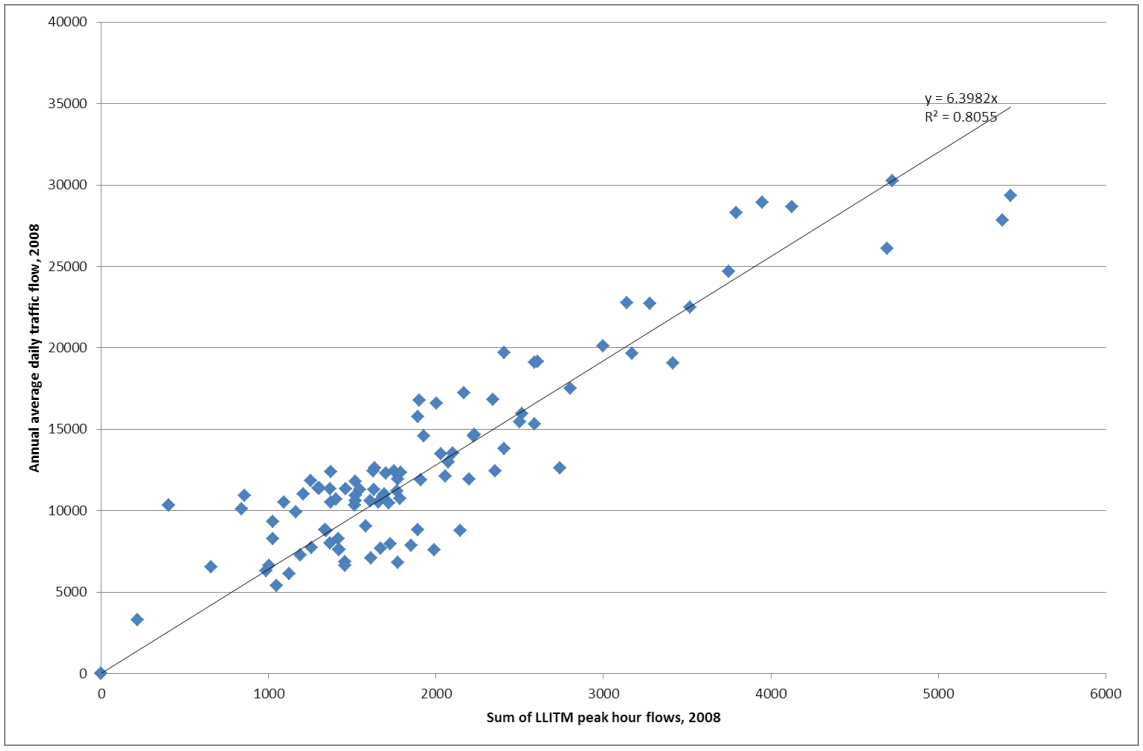
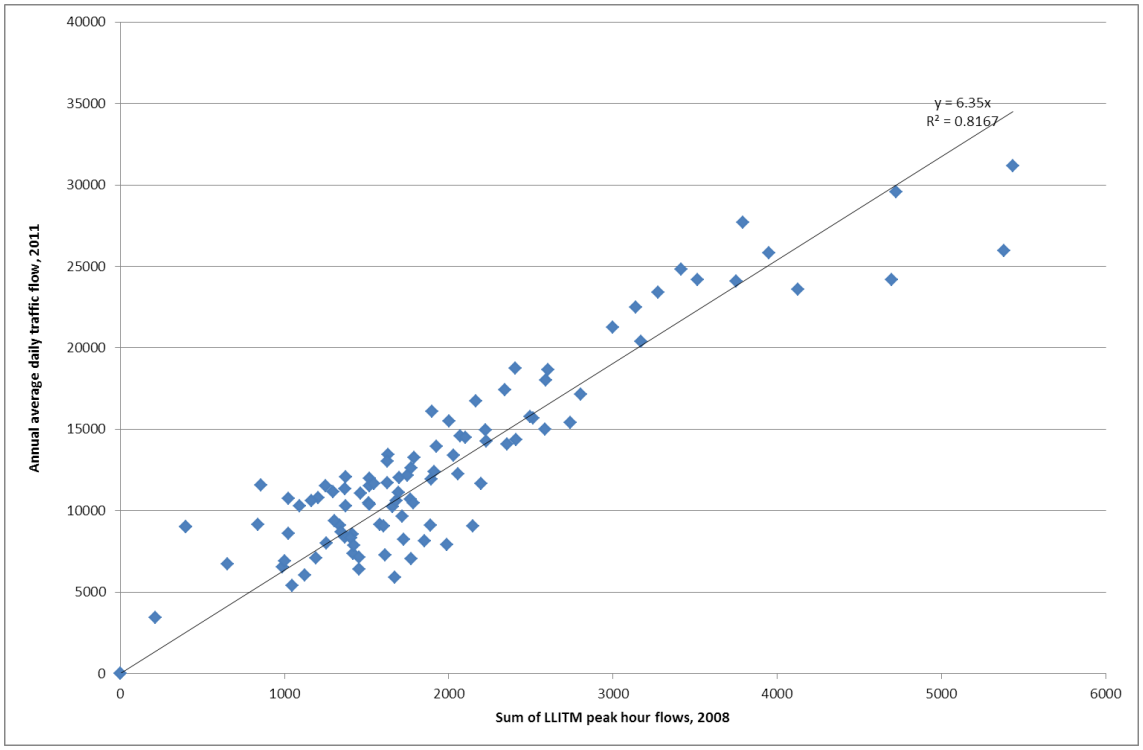


Fig. 5: Scatter plot of 2011 AADT flows against 2008 LLITM peak flows



2.4 Assignation of speed data to the LLITM network

Most of the busiest roads in Leicester are included in both the LLITM and TrafficMaster datasets. However, there is not a one-to-one correspondence between links representing the same road in the datasets. It was therefore necessary to assign speed data from the TrafficMaster network onto the LLITM links.

Shape files representing the two road networks were imported into an ESRI ArcMap GIS. Application of the GIS identified the TrafficMaster road link that was closest to the midpoint of each of the LLITM links. Further analysis then identified matches where:

- the TrafficMaster link was within 30 m of the midpoint of the LLITM link
- the general direction of flow (NE, SE, SW, NW) was the same

The morning and afternoon peak TrafficMaster speeds were then assigned to matching LLITM links. Average speeds were calculated for each link as the flow-weighted average of the peak speeds.

There were some LLITM links for which no match was obtained. An average speed of 30.9 kph was calculated from the matching links and applied to the non-matching links.

2.5 Assignation of traffic composition data

The location of the DfT traffic count points was plotted on a map of the LLITM network (Fig.1). LLITM road links on major roads corresponding to the DfT count points were then selected (manually) and the 2011 traffic composition data (e.g. percentage cars, LGV, rigid HGV, articulated HGV, buses and coaches, motorcycles) assigned to these links. The traffic composition for the nearest DfT count point was assigned to other links.

2.6 Emission factors

The Emission factor toolkit EFT 5.2 [2]was used to calculate the emissions of pollutants from each road link.

The toolkit includes Defra's currently recommended emission factors. It contains mathematical relationships between the emission factors for each pollutant and vehicle speed for a range of vehicle types:

- Petrol cars
- Diesel cars
- LGV
- Rigid HGV
- Artic HGV
- Buses and coaches
- Motorcycles

Vehicles sold in the European Union are required to meet increasingly stringent emission standards, designated Euro 1-6 for cars and light commercial vehicles and Euro I-VI for heavy duty vehicles. Table 1 shows when vehicles sold were required to meet the Euro standards. EFT provides emission factors for each Euro class. It also includes projections of the proportions of each Euro class in the fleet mix for each year and for each vehicle type. Appendix A1 lists emission factors for oxides of nitrogen, particulate matter PM_{10} and $PM_{2.5}$, and carbon dioxide calculated for the main vehicle types both for the 2011 vehicle fleet mix and for each Euro class.

Table 1: Euro class implementation dates

Vehicle class	Euro 1/I	Euro 2/II	Euro 3/III	Euro 4/IV	Euro 5/V	Euro 6/VI
Passenger cars	31 Dec 1992	1 January 1997	1 January 2001	1 January 2006	1 January 2011	1 September 2015
Light commercial Class I- up to 1.3 tonnes unladen weight	1 October 1994	1 January 1997	1 January 2001	1 January 2006	1 January 2011	1 September 2015
Light commercial Class II/III- between 1.3 tonnes unladen and 3.5 tonnes laden weight	1 October 1994	1 October 1998	1 January 2002	1 January 2007	1 January 2012	1 September 2016
Heavy duty-over 3.5 tonnes maximum laden weight	10 October 1993	1 October 1996	1 October 2001	1 October 2006	1 October 2009	1 January 2014

[2] http://laqm.defra.gov.uk/review-and-assessment/tools/emissions.html

2.7 Emission totals

Table 2 shows the total oxides of nitrogen emissions for 2011 and 2016 for the whole study area, for the whole AQMA and for each part of the AQMA. It also shows the calculated emissions for two example LEZs for 2016: a basic LEZ with buses and HGVs required to meet the Euro IV standard and an Ultra LEZ with buses and HGVs required to meet the Euro VI standard.

Tables 3-5 similarly show the emissions of particulate matter, PM_{10} and $PM_{2.5}$; and carbon dioxide.

Table 2: Oxides of nitrogen emissions by AQMA sector, kg per annum

Sector	Name	2011 base	2016 Base	2106 LEZ	2106 ultra LEZ
All		1142363	829486	804110	610292
AQMA		285036	213241	204829	152187
0	Central	83843	66045	63600	49060
1	New Parks Way	14557	10567	10337	8329
3	Hinckley Road	20197	15228	14428	9843
4	Narborough Road	11605	8569	8266	6513
5	Asquith Way	20630	14182	13898	10972
6	Groby Road	7849	5989	5634	3756
7	Devonshire Road	14004	10741	10508	8714
8	London Road	12119	9061	8524	5707
9	Melton Road	30379	22850	21846	15874
10	Humberstone Road	24233	18260	17169	11191
11	Uppingham Road	2717	1778	1733	1216
12	Goodwood Road	7273	5199	5082	3812
14	Aylestone Road	14044	9352	8949	6100
15	Saffron Lane	11681	7782	7463	5072
16	Welford Road	9904	7638	7392	6026

Table 3: PM_{10} emissions by AQMA sector, kg per annum

Sector	Name	2011 base	2016 Base	2106 LEZ	2106 ultra LEZ
All		81436	71925	70734	69268
AQMA		19552	17136	16774	16344
0	Central	5847	5294	5192	5073
1	New Parks Way	1109	971	960	945
3	Hinckley Road	1337	1202	1168	1132
4	Narborough Road	869	744	731	717
5	Asquith Way	1512	1261	1245	1221
6	Groby Road	460	378	364	346
7	Devonshire Road	1123	1027	1016	1002
8	London Road	767	664	643	620
9	Melton Road	2057	1802	1760	1712
10	Humberstone Road	1421	1229	1185	1136
11	Uppingham Road	174	151	149	145
12	Goodwood Road	506	459	453	443
14	Aylestone Road	882	698	679	654
15	Saffron Lane	730	588	573	554
16	Welford Road	757	667	657	646

Table 4: $PM_{2.5}$ emissions by AQMA sector, kg per annum

Sector	Name	2011 base	2016 Base	2106 LEZ	2106 ultra LEZ
All		54105	43434	42303	40910
AQMA		13191	10473	10130	9721
0	Central	3944	3239	3142	3029
1	New Parks Way	733	584	573	559
3	Hinckley Road	899	733	701	667
4	Narborough Road	584	454	442	428
5	Asquith Way	1018	768	753	729
6	Groby Road	328	241	227	210
7	Devonshire Road	745	620	609	596
8	London Road	519	409	389	367
9	Melton Road	1390	1102	1062	1017
10	Humberstone Road	980	763	722	674
11	Uppingham Road	116	91	88	85
12	Goodwood Road	333	275	269	260
14	Aylestone Road	605	430	412	388
15	Saffron Lane	494	359	344	326
16	Welford Road	504	405	395	385

Table 5: Carbon dioxide emissions by AQMA sector tonnes per annum

Sector	Name	2011 base	2016 Base	2106 LEZ	2106 ultra LEZ
All		360460	358751	358358	358666
AQMA		90532	90928	90811	90918
0	Central	27642	28539	28507	28537
1	New Parks Way	4835	4735	4731	4734
3	Hinckley Road	5924	6092	6081	6090
4	Narborough Road	4038	3919	3915	3919
5	Asquith Way	7117	6812	6807	6811
6	Groby Road	2311	2397	2392	2397
7	Devonshire Road	4951	5034	5030	5033
8	London Road	3625	3595	3589	3595
9	Melton Road	9466	9513	9499	9512
10	Humberstone Road	6707	6877	6863	6877
11	Uppingham Road	754	754	753	754
12	Goodwood Road	2275	2307	2305	2306
14	Aylestone Road	4143	3884	3878	3883
15	Saffron Lane	3290	3092	3087	3091
16	Welford Road	3453	3380	3377	3379

3 Source apportionment studies

3.1 Introduction

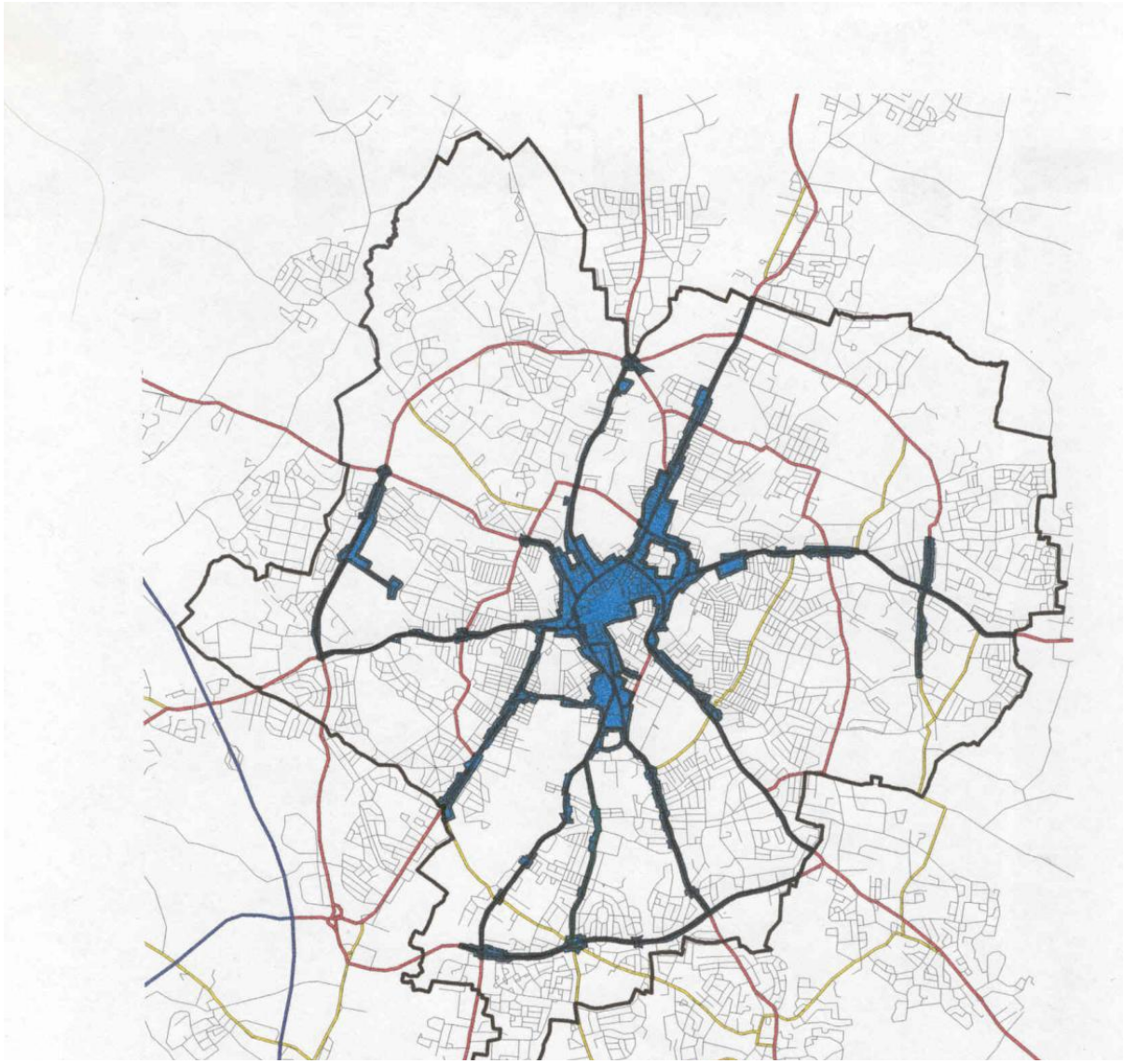
This section describes the source apportionment of oxides of nitrogen and primary nitrogen dioxide emissions for specific road links in the Leicester City AQMA. It then describes how the calculated emissions were used to carry out a source apportionment of nitrogen dioxide concentrations measured at monitoring sites in the Leicester AQMA. The method was then applied to estimate the concentrations at these monitoring sites for example future scenarios.

3.1.1 Air quality management area

Fig. 6 shows the Leicester Air Quality Management Area. It covers a large part of the main road network in the city. Roads in the AQMA include:

- Radial roads(clockwise from the south-west):
  - A5460 Narborough Road
  - A47 Hinckley Road
  - A50 Woodgate/Frog Island
  - A6 Abbey Lane
  - A607 Belgrave Road/ Melton Road
  - A47 Harberstone Road/Uppingham Road
  - A6 London Road
  - A5199 Welford Road
  - A426 Aylestone Road
- Outer ring road
  - Western sector: A563 New Parks Way
  - Southern sector: A563 Soar Valley Way, Glenhills Way, Attlee Way, Asquith Way, Palmerston Way
  - Eastern Sector; A563 Colchester Road
- A594 one-way system
  - Almond Road
  - Aylesford road
  - Welford Road
  - Oxford Street
- A594 Inner ring road
  - Vaughan Way
  - Burleys Way
  - St Matthews Way
  - St Georges Way
  - Tigers Way

Fig. 6: Leicester City AQMA



3.1.2 Department for Transport manual counts

The Department for Transport provides annual classified traffic counts for 55 locations throughout Leicester City. Fig. 7 shows the locations of the count points and the Identification number. Table 6 provides a summary of traffic flows for 2011 t count points in the AQMA.

Fig. 7: Dft count points and monitoring sites in Leicester City

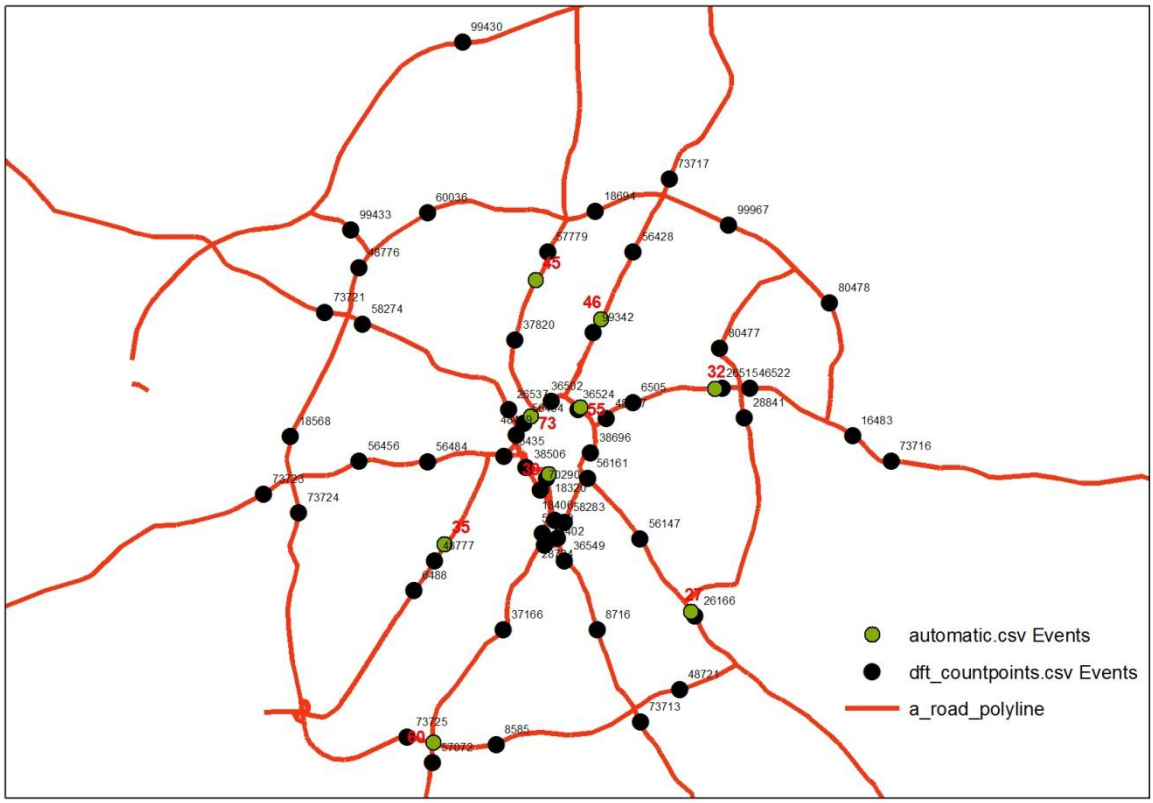


Table 6: Traffic flows at count points in the AQMA

Road	Road name	Count point	2-way AADT	% Car	% LGV	% Rigid HGV	% Artic HGV	% Bus and Coach	% Motorcycle
Radial roads									
A5460	Narborough Road	48777	26501	86.4	9.8	1.5	0.4	1.4	0.6
		6488	30671	81.5	14.5	1.5	0.3	1.7	0.6
A47	Hinckley Road	56456	18156	82.5	11.0	2.3	0.6	3.2	0.5
		56484	16451	80.3	13.9	1.4	0.3	3.5	0.7
A50	Woodgate/Frog Island	26537	20225	76.9	16.3	2.3	0.4	3.3	0.8
A6	Abbey Lane	57779	24711	83.1	12.8	1.5	0.4	1.0	1.2
		37820	20307	82.9	13.8	1.5	0.3	0.6	0.9
A607	Belgrave Road/Melton Road	73717	27619	82.0	12.6	2.4	1.8	0.8	0.4
		56428	14196	77.9	16.6	2.2	0.5	2.2	0.6
		99342	27686	86.6	8.6	0.9	0.2	3.3	0.4
A47	Harberstone Road/Uppingham Road	48677	30039	81.5	12.5	1.7	0.5	3.2	0.5
		6505	22642	81.4	11.3	2.3	0.7	3.7	0.7
		26515	14466	79.4	13.2	1.7	0.5	4.8	0.3
		46522	15238	78.3	16.3	2.0	0.4	2.6	0.4
		16483	11429	78.5	13.8	3.1	3.1	1.1	0.4
		73716	12326	78.6	14.2	3.4	2.9	0.6	0.4
A6	London Road	56161	21317	83.6	8.9	1.2	0.2	5.6	0.5
		56147	20689	87.1	8.9	1.1	0.4	1.9	0.6
		26166	19986	86.2	9.1	1.1	0.5	2.7	0.5
A5199	Welford Road	36549	24046	88.2	9.1	0.9	0.2	0.9	0.7
		8716	23547	84.5	12.3	0.9	0.1	1.6	0.6
		73713	17360	87.5	8.3	1.6	0.3	1.5	0.7
A426	Aylestone Road	37166	16366	80.2	11.9	4.3	0.8	1.7	1.1
Outer ring road									
A563 W	New Parks Way	18568	21050	82.8	13.1	2.4	0.7	0.4	0.7
A563 S	Southern ring road	73725	46645	83.6	11.9	2.5	1.2	0.1	0.6
		8585	32894	83.1	11.9	2.6	1.4	0.5	0.4
		48721	22303	84.2	12.0	2.0	1.2	0.1	0.5
A563 E	Colchester Road	80478	25031	85.9	8.6	3.2	1.5	0.4	0.5
A594 one way system									
	Almond Road	48402	15080	81.9	13.4	2.6	0.3	1.3	0.5
	Aylesford Road	58099	24080	81.8	13.5	1.6	0.2	2.1	0.9
	Welford Road	28724	27692	84.3	12.1	1.2	0.2	1.6	0.7
		18406	25825	83.1	12.6	1.5	0.2	2.0	0.7
		18320	24185	84.6	10.9	1.1	0.1	2.4	0.9
	Oxford Street	70290	25964	83.9	11.5	1.1	0.2	2.4	1.0
Inner ring road									
A594	Vaughn Way	38506	42697	85.0	11.9	1.3	0.2	0.8	0.9

Inner ring road		48489	60708	84.8	10.7	1.3	0.2	2.1	0.9
		56464	43986	83.3	11.3	1.6	0.4	2.7	0.7
	Burleys Way	36502	48189	84.4	11.6	1.6	0.6	1.1	0.7
	St Matthews Way	36524	39994	85.3	11.6	1.9	0.6	0.2	0.5
	St Georges Way	38696	35341	87.7	10.0	1.4	0.2	0.2	0.4
	Tigers Way	58283	17288	84.4	12.7	1.8	0.3	0.4	0.4

3.1.3 Source apportionment of oxides of nitrogen

Defra's Emission factor toolkit was used to calculate the proportion of emissions of oxides of nitrogen emitted for different classes of vehicle at each of the count points in the AQMA. The appropriate speed for each link was determined from the Leicester Airviro model database. Table 7 shows the calculated source apportionment at each count point in the AQMA.

Table 7: Source apportionment of oxides of nitrogen emissions

Road	Road name		Petrol Cars (%)	Diesel Cars (%)	Petrol LGV (%)	Diesel LGV (%)	Rigid HGV (%)	Artic HGV (%)	Buses/ Coaches (%)	Motorcycles (%)
Radial roads										
A5460	Narborough Road	48777	17.2%	35.8%	0.4%	14.5%	12.2%	4.3%	15.4%	0.2%
		6488	15.5%	31.5%	0.6%	20.1%	11.4%	3.0%	17.7%	0.2%
A47	Hinckley Road	56456	11.2%	25.7%	0.3%	12.0%	15.2%	5.5%	29.9%	0.1%
		56484	12.3%	26.5%	0.4%	16.3%	9.3%	2.6%	32.4%	0.1%
A50	Woodgate/Frog Island	26537	10.1%	23.1%	0.4%	17.2%	15.2%	3.6%	30.2%	0.1%
A6	Abbey Lane	57779	16.1%	34.6%	0.5%	19.1%	12.6%	5.2%	11.7%	0.3%
		37820	17.3%	36.2%	0.6%	21.5%	13.3%	4.1%	6.8%	0.3%
A607	Belgrave Road/Melton Road	73717	13.1%	28.2%	0.4%	15.4%	17.4%	17.5%	7.8%	0.1%
		56428	11.3%	26.0%	0.4%	19.5%	16.0%	4.8%	21.9%	0.1%
		99342	13.4%	30.7%	0.2%	10.7%	6.8%	2.7%	35.4%	0.1%
A47	Harberstone Road/Uppingham Road	48677	12.4%	26.7%	0.4%	14.6%	11.7%	4.9%	29.3%	0.1%
		6505	12.0%	25.0%	0.3%	12.3%	14.1%	5.7%	30.4%	0.1%
		26515	9.1%	21.6%	0.3%	12.5%	10.5%	4.3%	41.8%	0.0%
		46522	11.2%	25.5%	0.4%	18.7%	14.1%	4.3%	25.7%	0.1%
		16483	9.0%	21.3%	0.3%	13.0%	18.6%	28.0%	9.8%	0.0%
		73716	9.9%	22.7%	0.3%	14.4%	20.8%	26.2%	5.6%	0.1%
A6	London Road	56161	11.4%	24.5%	0.2%	9.3%	7.3%	1.3%	45.8%	0.1%
		56147	16.4%	35.1%	0.3%	12.7%	9.2%	4.4%	21.6%	0.2%
		26166	14.3%	31.7%	0.3%	11.8%	8.2%	5.3%	28.3%	0.1%
A5199	Welford Road	36549	19.5%	41.9%	0.4%	15.5%	8.7%	2.2%	11.7%	0.2%
		8716	16.2%	35.9%	0.5%	18.5%	7.9%	1.2%	19.7%	0.1%
		73713	17.7%	35.9%	0.4%	12.2%	13.4%	3.4%	16.7%	0.2%
A426	Aylestone Road	37166	11.6%	25.0%	0.3%	13.2%	27.9%	7.2%	14.6%	0.2%
Outer ring road										
A563 W	New Parks Way	18568	15.4%	33.0%	0.5%	18.5%	19.4%	8.1%	5.0%	0.2%
A563 S	Southern ring road	73725	15.7%	32.6%	0.5%	16.6%	20.0%	13.0%	1.4%	0.2%
		8585	13.0%	29.8%	0.3%	15.0%	20.4%	16.1%	5.3%	0.1%
		48721	15.3%	34.0%	0.4%	17.2%	17.1%	14.3%	1.5%	0.1%
A563 E	Colchester Road	80478	11.8%	29.2%	0.2%	10.0%	25.4%	18.2%	5.2%	0.1%
A594 one way system										
	Almond Road	48402	14.3%	30.7%	0.5%	18.0%	20.4%	2.9%	13.1%	0.1%
	Aylesford Road	58099	13.3%	30.4%	0.4%	17.6%	12.6%	2.1%	23.5%	0.2%
	Welford Road	28724	16.2%	34.8%	0.5%	17.8%	10.3%	2.3%	17.9%	0.2%
		18406	14.9%	32.1%	0.5%	17.3%	11.8%	1.7%	21.6%	0.2%
		18320	14.2%	32.4%	0.3%	14.7%	9.4%	0.8%	28.0%	0.2%
	Oxford Street	70290	12.5%	30.8%	0.3%	14.4%	9.5%	2.0%	30.3%	0.2%
Inner ring road										
A594	Vaughn Way	38506	16.1%	38.3%	0.4%	18.6%	12.6%	2.6%	11.2%	0.2%

Inner ring road		48489	14.3%	32.6%	0.3%	14.5%	11.1%	3.0%	24.1%	0.2%
		56464	13.7%	29.4%	0.4%	14.1%	11.9%	4.1%	26.3%	0.2%
	Burleys Way	36502	15.4%	34.0%	0.4%	16.6%	13.6%	6.8%	13.1%	0.1%
	St Matthews Way	36524	14.7%	36.4%	0.3%	16.9%	19.6%	9.5%	2.5%	0.1%
	St Georges Way	38696	19.8%	42.5%	0.5%	17.3%	14.0%	2.6%	3.3%	0.1%
	Tigers Way	58283	17.8%	37.2%	0.6%	20.0%	16.2%	3.3%	4.9%	0.1%

Fig. 8 shows the proportions of oxides of nitrogen by specific vehicle types for the radial road links. Diesel cars make the largest contribution to oxides of nitrogen emissions on the A5460 Narborough Road (48777, 6488). Petrol cars, diesel LGVs, rigid HGVs and buses and coaches also make a substantial contribution. Buses make the largest contribution to emissions on the A47 Hinckley Road (56456, 56484) and on the A50 Woodgate/Frog Island (26537). Diesel cars, petrol cars, diesel LGVs and rigid HGVs s also make a substantial contribution. Diesel cars and diesel LGVs make the largest contribution on the A6 Abbey Lane (57779, 37820). Diesel cars make a substantial contribution on A607 Belgrave Road/Melton Road. Rigid and articulated HGV make a substantial contribution outside the outer ring road (73717) but buses make an increasing contribution on this route towards the city centre (99342). The situation on the A47 Harberstone Road/Uppingham Road is similar with substantial HGV contribution outside the outer ring road (16483,73716) and substantial bus contributions nearer to the city centre (48677, 6505, 26515).Buses make a relatively large contribution on the A6 London Road, particularly close to the city centre (56161). Diesel cars also make a substantial contribution on this route. Diesel cars make the largest contribution on the A5199 Welford Road (8716, 73713). Rigid HGVs make the largest contribution on the A426 Aylestone Road(37166).

Fig. 9 shows a similar source apportionment for sections of the outer ring road within the AQMA. The road links are broadly similar, with diesel cars making the largest contribution and substantial contributions from rigid and articulated HGVs.

Fig. 10 shows a similar source apportionment for the A594 one-way system the south of the city centre. The road links are broadly similar: the highest contribution is from diesel cars with a substantial contribution from buses. There is a relatively high proportion of rigid HGVs on Almond Road (48402), which forms a 2-way connecting link between the A5199 Welford Road and the A426 Aylestone Road.

Fig. 11: shows the source apportionment for the A594 inner ring road. Diesel cars make the largest contribution to emissions on these links. Buses make a substantial contribution on Vaughan Way (48489, 56464).

Fig. 8: Source apportionment of oxides of nitrogen, radial roads

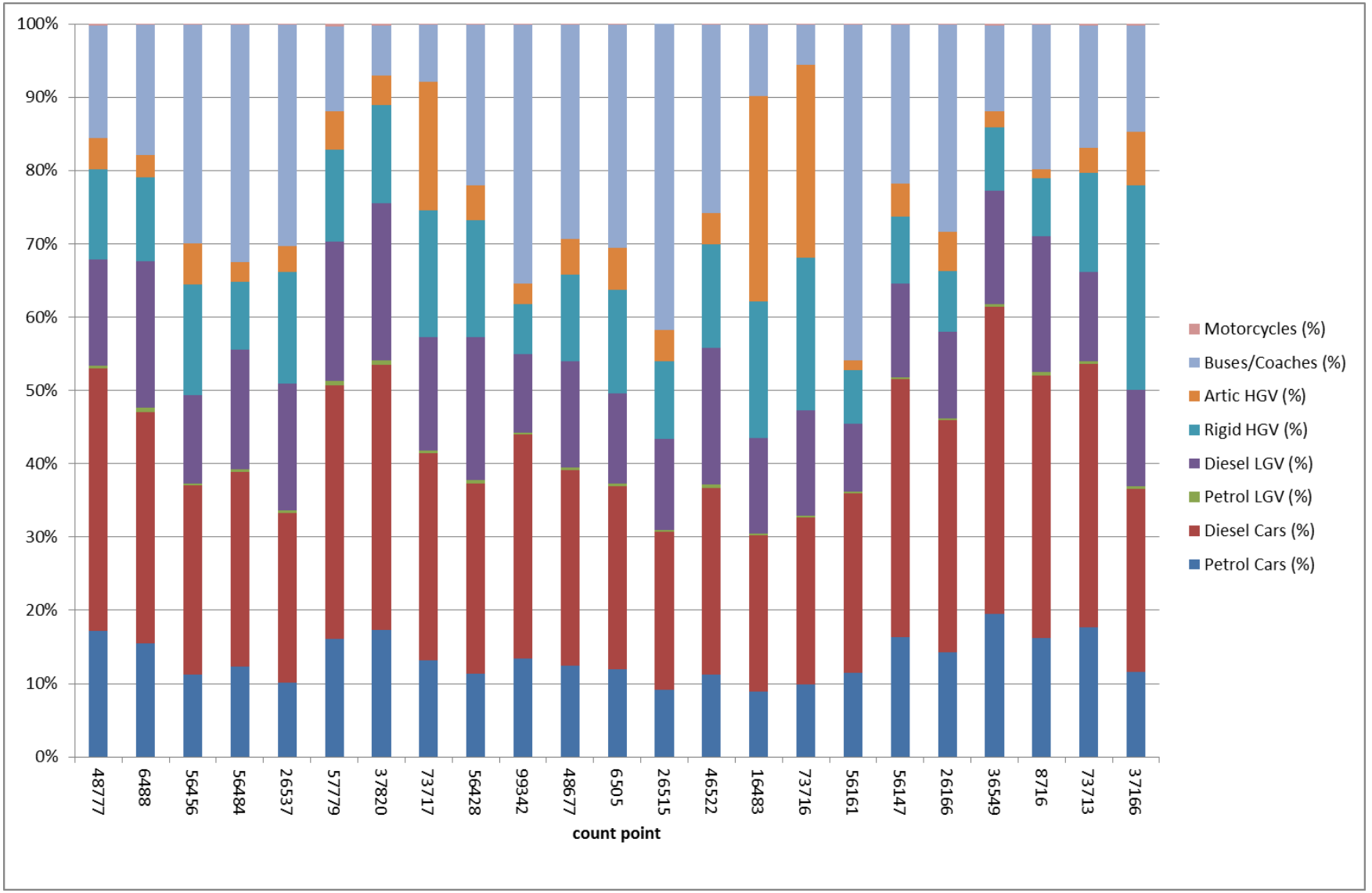


Fig. 9: Source apportionment of oxides of nitrogen, outer ring road

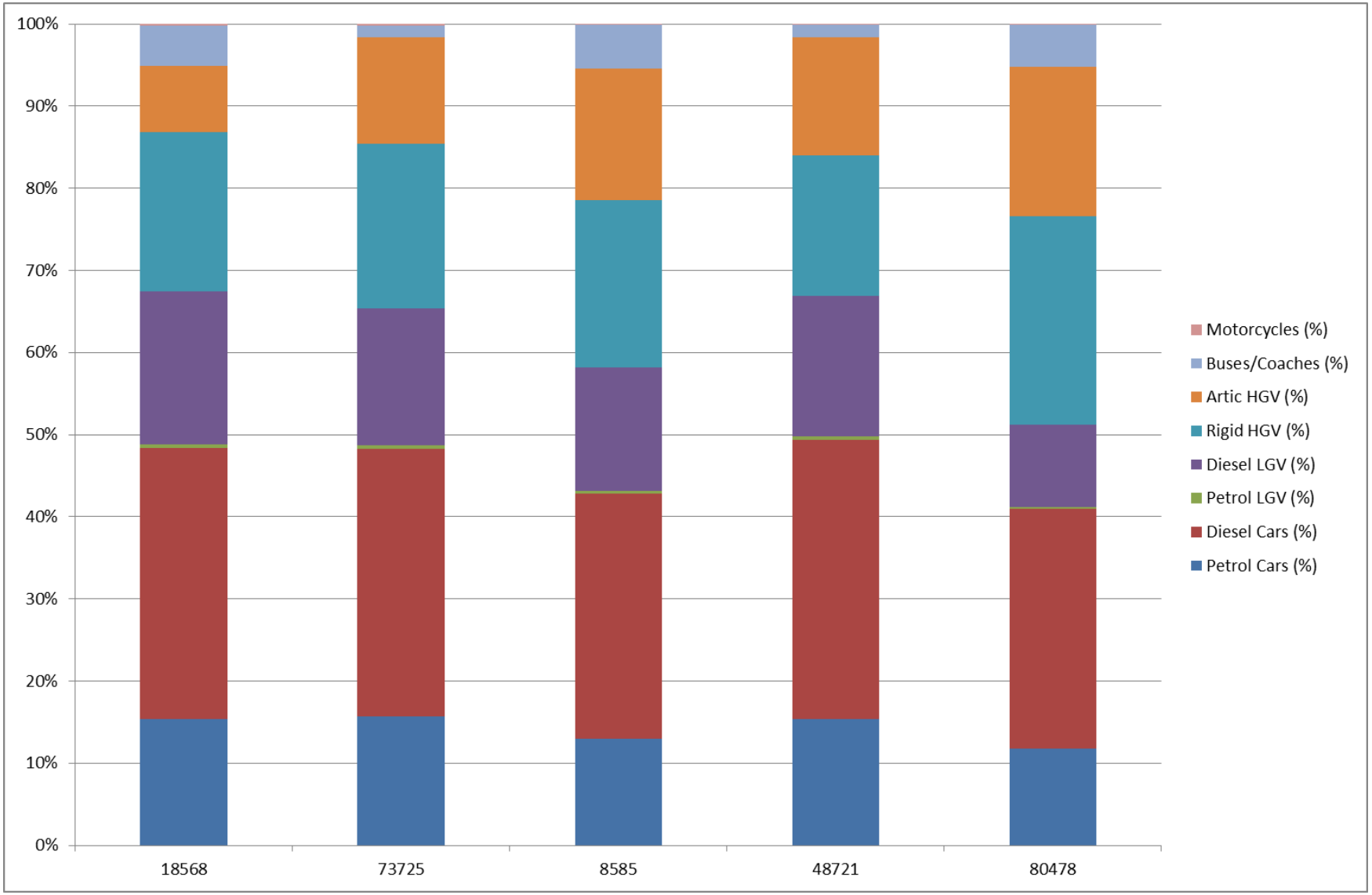


Fig. 10: Source apportionment of oxides of nitrogen, A594 one-way system

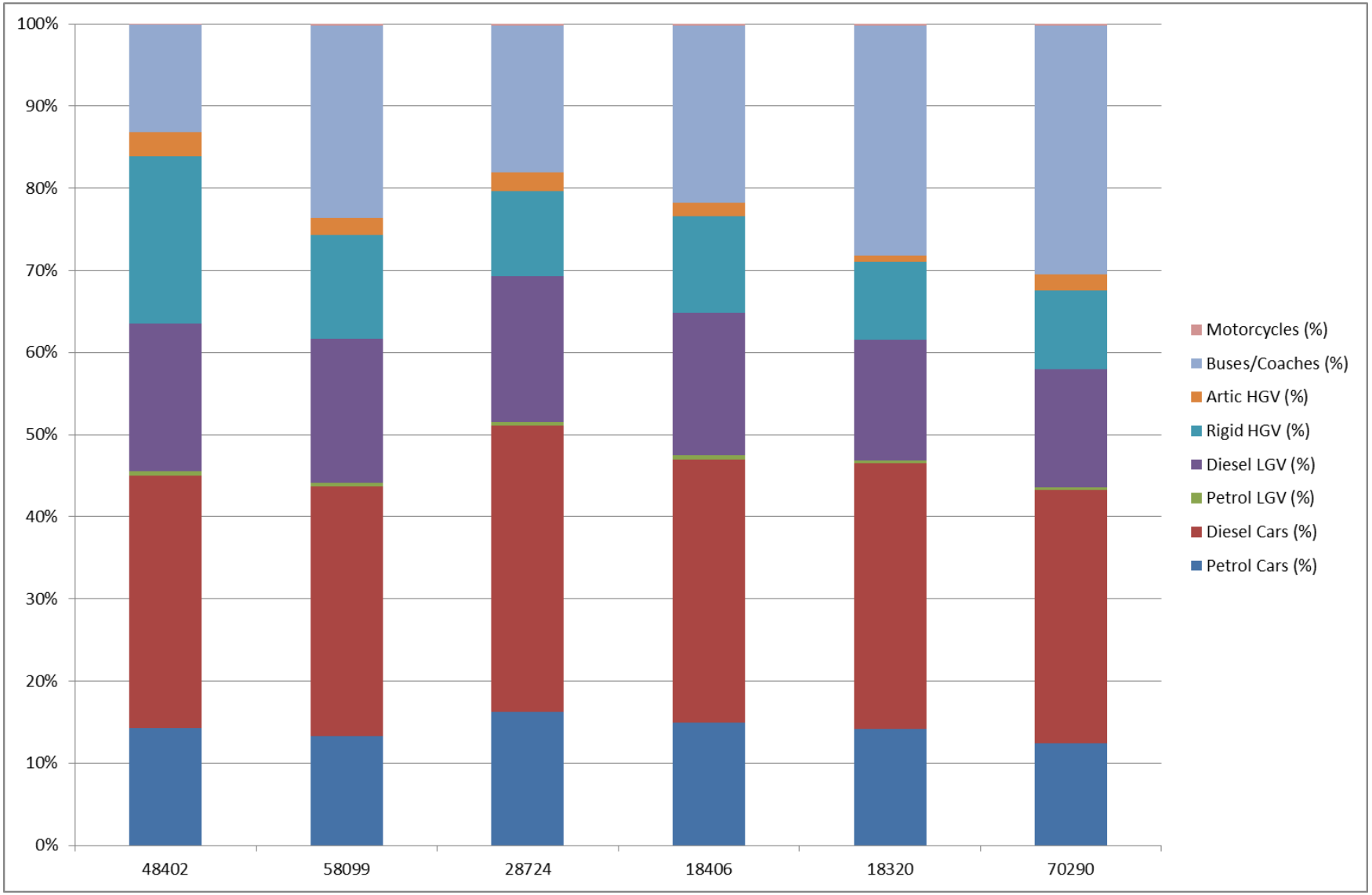
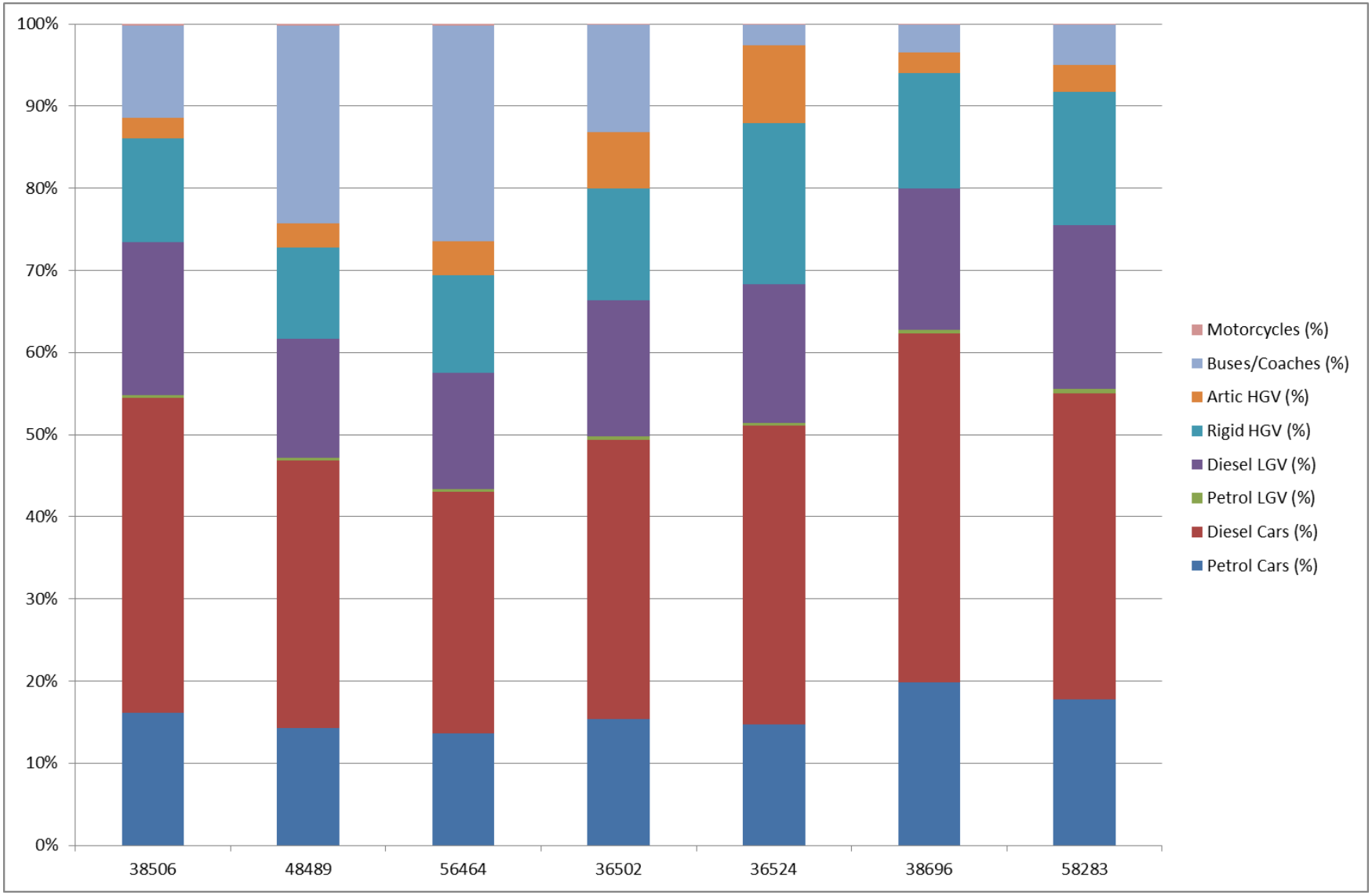


Fig. 11: Source apportionment of oxides of nitrogen, inner ring road



3.1.4 Source apportionment of primary nitrogen dioxide

The proportion of primary nitrogen dioxide emissions was estimated from the oxides of nitrogen emissions for each road link, using Defra primary nitrogen dioxide factors for each vehicle category, shown in Table 8.

Table 8: Primary nitrogen dioxide factors

Euro class	Petrol Cars	Diesel Cars	Petrol LGV	Diesel LGV	Rigid HGV	Artic HGV	Buses/Coaches	Motorcycles
2011 fleet	0.031	0.420	0.034	0.446	0.125	0.119	0.125	0.04
2016 fleet	0.028	0.398	0.030	0.406	0.108	0.102	0.112	0.04
Pre-Euro 1	0.04	0.11	0.04	0.11	0.11	0.11	0.11	n/a
Euro 1	0.04	0.11	0.04	0.11	0.11	0.11	0.11	n/a
Euro 2	0.04	0.11	0.04	0.11	0.11	0.11	0.11	n/a
Euro 3	0.03	0.25	0.03	0.25	0.14	0.14	0.14	n/a
Euro 4	0.03	0.55	0.03	0.55	0.14	0.14	0.14	n/a
Euro 5	0.03	0.4	0.03	0.4	0.1	0.1	0.1	n/a
Euro 6	0.02	0.3	0.02	0.3	0.1	0.1	0.1	n/a
Euro 3 with DPF	n/a	0.35	n/a	0.35	n/a	n/a	n/a	n/a
Euro 4 with DPF	n/a	0.55	n/a	0.55	n/a	n/a	n/a	n/a

Table 9 shows the primary nitrogen dioxide source apportionment. Figs. 12-15 show the source apportionment of primary nitrogen dioxide for the radial roads, outer ring road, A594 one-way system south of the city centre and the inner ring road.

In general, the apportionment of heavy duty vehicles is similar to that for oxides of nitrogen. However, the contribution from diesel cars and diesel light goods vehicles is much higher because of the relatively high primary nitrogen dioxide factors for these vehicles.

Table 9: Source apportionment of primary nitrogen dioxide emissions

Road	Road name	Count point	Petrol Cars (%)	Diesel Cars (%)	Petrol LGV (%)	Diesel LGV (%)	Rigid HGV (%)	Artic HGV (%)	Buses/ Coaches (%)	Motorcycles (%)
Radial roads										
A5460	Narborough Road	48777	2.1%	57.8%	0.1%	24.9%	5.9%	2.0%	7.4%	0.0%
		6488	1.8%	49.6%	0.1%	33.5%	5.3%	1.4%	8.3%	0.0%
A47	Hinckley Road	56456	1.5%	47.4%	0.0%	23.5%	8.3%	2.9%	16.3%	0.0%
		56484	1.6%	45.8%	0.1%	29.9%	4.8%	1.3%	16.6%	0.0%
A50	Woodgate/Frog Island	26537	1.3%	40.8%	0.1%	32.2%	8.0%	1.8%	15.8%	0.0%
A6	Abbey Lane	57779	1.9%	53.5%	0.1%	31.2%	5.8%	2.3%	5.3%	0.0%
		37820	1.9%	53.6%	0.1%	33.8%	5.9%	1.7%	3.0%	0.0%
A607	Belgrave Road/Melton Road	73717	1.7%	48.6%	0.1%	28.1%	8.9%	8.6%	4.0%	0.0%
		56428	1.4%	43.2%	0.1%	34.3%	7.9%	2.2%	10.8%	0.0%
		99342	1.8%	54.4%	0.0%	20.1%	3.6%	1.4%	18.6%	0.0%
A47	Harberstone Road/Uppingham Road	48677	1.6%	47.1%	0.1%	27.3%	6.2%	2.4%	15.3%	0.0%
		6505	1.7%	46.4%	0.1%	24.3%	7.8%	3.0%	16.8%	0.0%
		26515	1.3%	41.3%	0.0%	25.4%	6.0%	2.3%	23.7%	0.0%
		46522	1.4%	43.1%	0.1%	33.4%	7.1%	2.0%	12.9%	0.0%
		16483	1.3%	40.8%	0.0%	26.5%	10.6%	15.3%	5.6%	0.0%
		73716	1.4%	42.0%	0.0%	28.3%	11.5%	13.8%	3.1%	0.0%
A6	London Road	56161	1.7%	47.7%	0.0%	19.2%	4.2%	0.7%	26.4%	0.0%
		56147	2.0%	58.3%	0.0%	22.4%	4.5%	2.1%	10.6%	0.0%
		26166	1.9%	54.9%	0.0%	21.7%	4.2%	2.6%	14.6%	0.0%
A5199	Welford Road	36549	2.2%	63.0%	0.0%	24.7%	3.9%	0.9%	5.2%	0.0%
		8716	1.9%	55.0%	0.1%	30.0%	3.6%	0.5%	8.9%	0.0%
		73713	2.2%	59.7%	0.0%	21.5%	6.6%	1.6%	8.2%	0.0%
A426	Aylestone Road	37166	1.6%	45.8%	0.1%	25.6%	15.2%	3.8%	7.9%	0.0%
Outer ring road										
A563 W	New Parks Way	18568	1.8%	52.1%	0.1%	31.0%	9.1%	3.6%	2.3%	0.0%
A563 S	Southern ring road	73725	1.9%	53.0%	0.1%	28.7%	9.7%	6.0%	0.7%	0.0%
		8585	1.7%	50.6%	0.0%	27.0%	10.3%	7.7%	2.7%	0.0%
		48721	1.8%	54.0%	0.1%	28.9%	8.1%	6.5%	0.7%	0.0%
A563 E	Colchester Road	80478	1.6%	53.1%	0.0%	19.3%	13.7%	9.4%	2.8%	0.0%
A594 one way system										
	Almond Road	48402	1.7%	49.8%	0.1%	30.9%	9.8%	1.4%	6.3%	0.0%
	Aylesford Road	58099	1.6%	49.5%	0.1%	30.4%	6.1%	0.9%	11.3%	0.0%
	Welford Road	28724	1.9%	54.4%	0.1%	29.5%	4.8%	1.0%	8.3%	0.0%
		18406	1.8%	51.7%	0.1%	29.6%	5.6%	0.8%	10.3%	0.0%
		18320	1.8%	53.6%	0.0%	25.8%	4.6%	0.4%	13.8%	0.0%
	Oxford Street	70290	1.6%	51.8%	0.0%	25.7%	4.8%	1.0%	15.1%	0.0%
Inner ring road										
A594	Vaughn Way	38506	1.8%	57.1%	0.0%	29.4%	5.6%	1.1%	4.9%	0.0%

Inner ring road		48489	1.8%	54.1%	0.0%	25.4%	5.5%	1.4%	11.8%	0.0%
		56464	1.8%	50.7%	0.1%	25.9%	6.1%	2.0%	13.5%	0.0%
	Burleys Way	36502	1.8%	54.3%	0.1%	28.1%	6.4%	3.1%	6.2%	0.0%
	St Matthews Way	36524	1.7%	56.3%	0.0%	27.6%	9.0%	4.2%	1.2%	0.0%
	St Georges Way	38696	2.2%	62.3%	0.1%	26.8%	6.1%	1.1%	1.4%	0.0%
	Tigers Way	58283	2.0%	55.5%	0.1%	31.7%	7.2%	1.4%	2.2%	0.0%

Fig. 12: Source apportionment primary nitrogen dioxide, radial roads

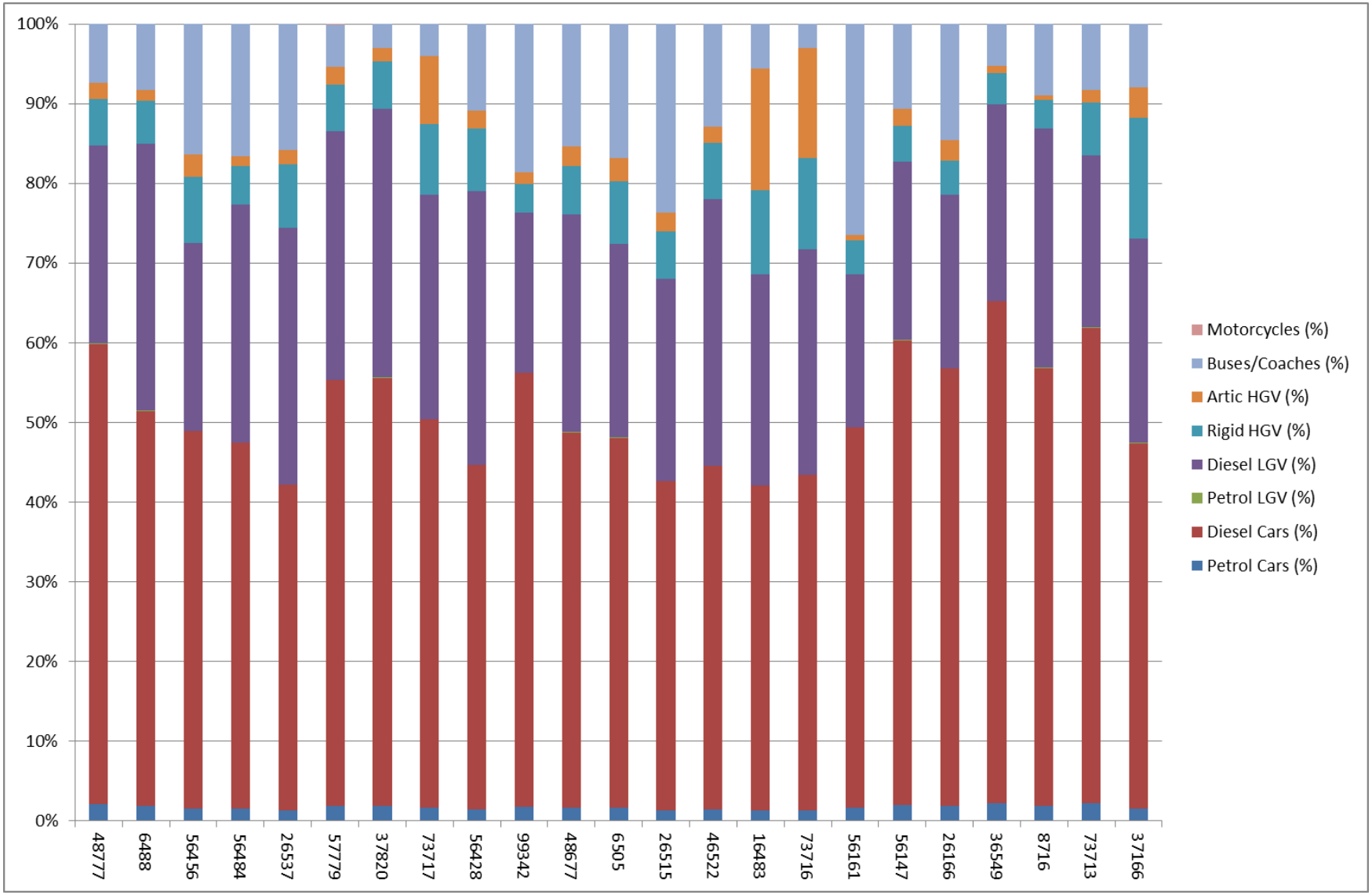


Fig. 13: Source apportionment primary nitrogen dioxide, outer ring road

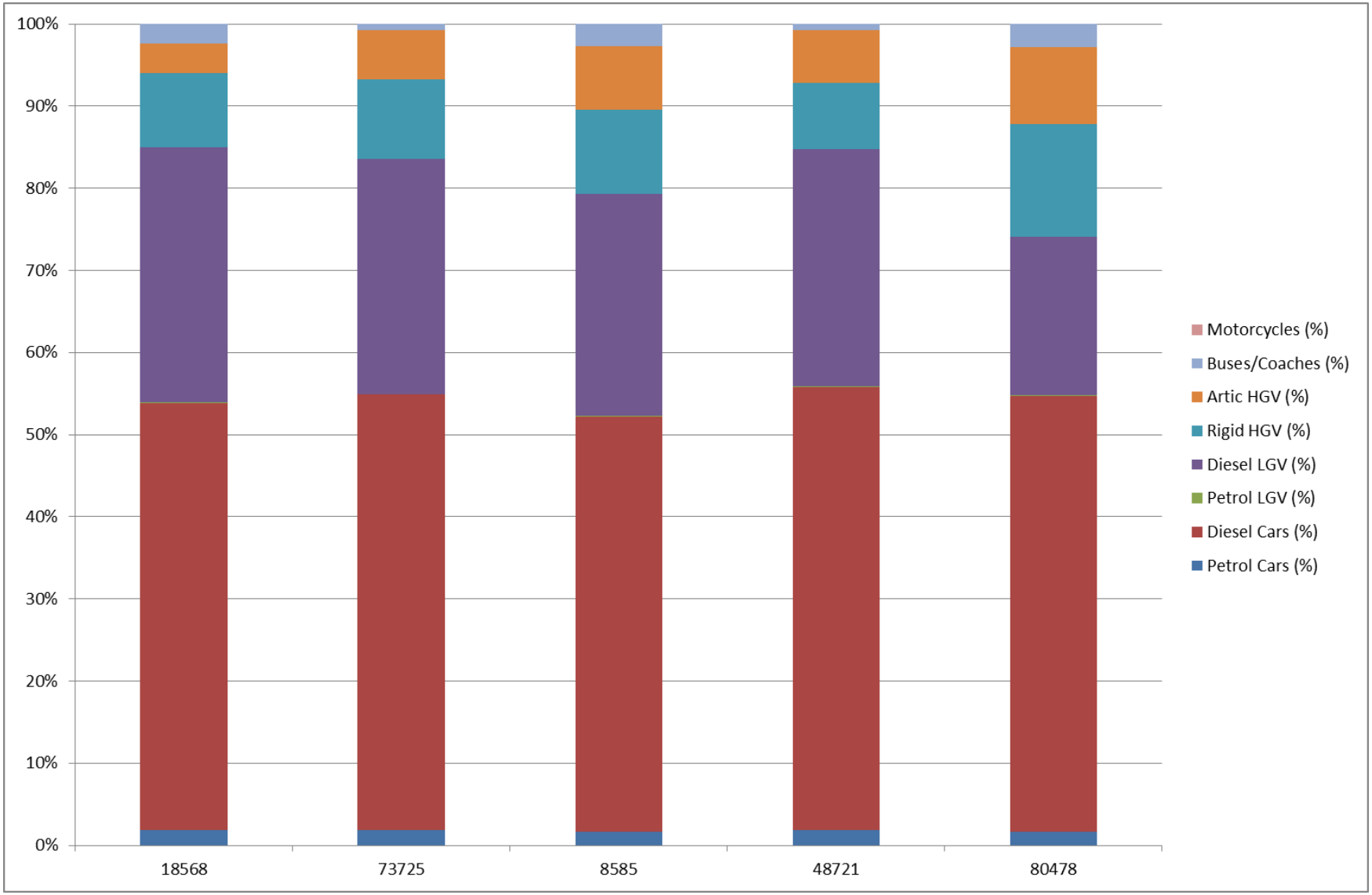


Fig. 14: Source apportionment of primary nitrogen dioxide, A594 one-way system

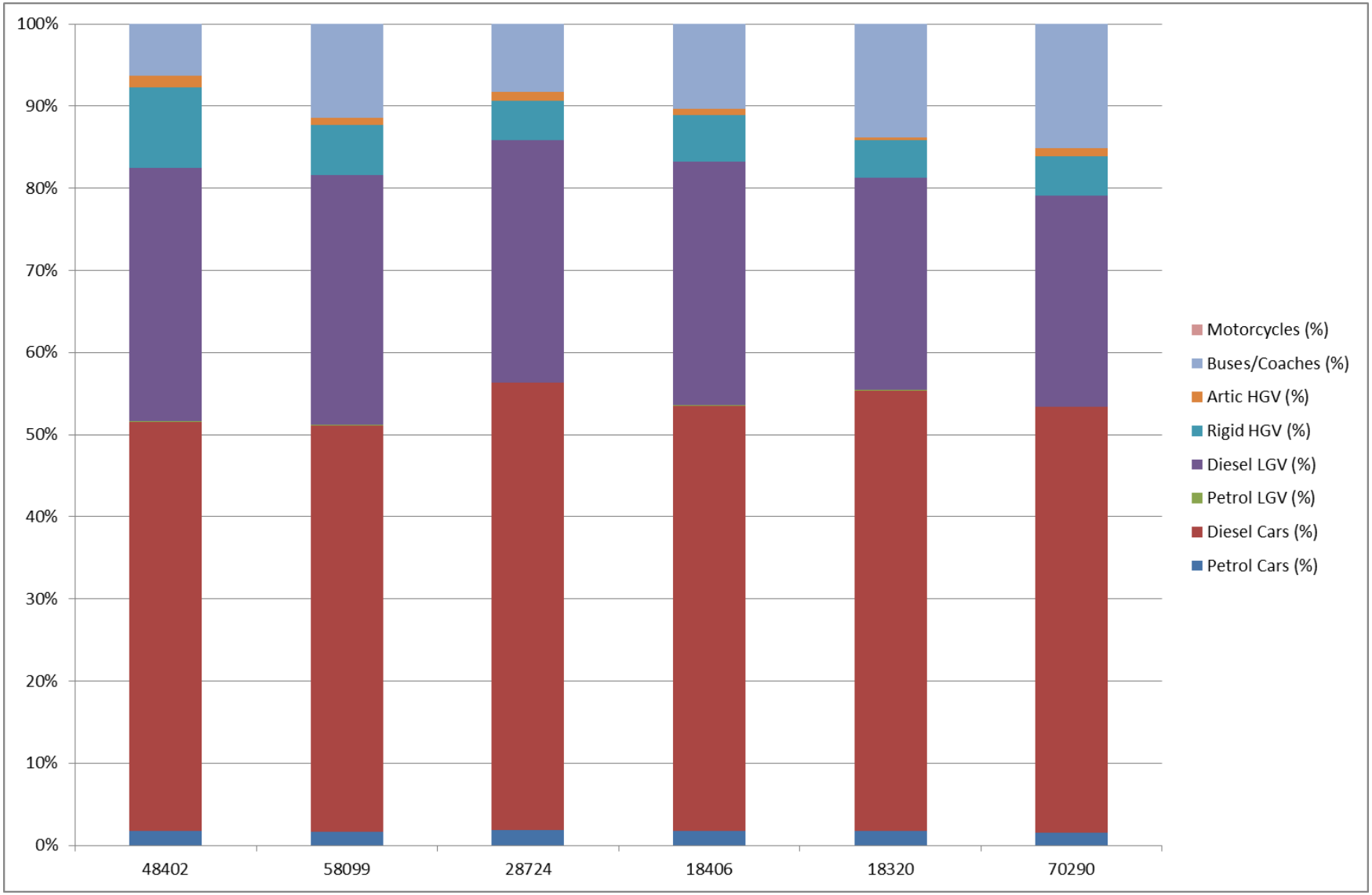
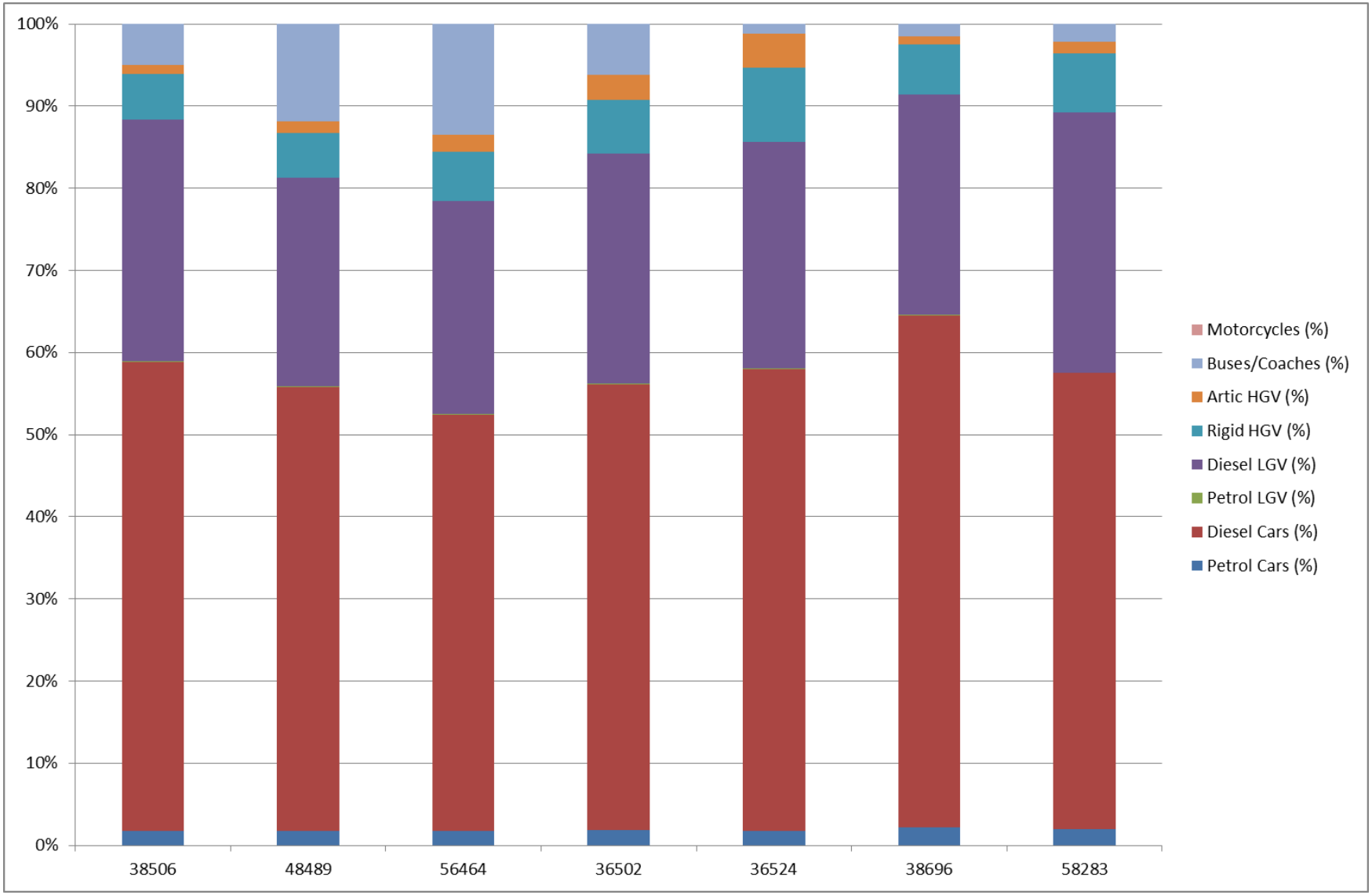


Fig. 15: Source apportionment of primary nitrogen dioxide, inner ring road



3.1.5 Source apportionment of measured nitrogen dioxide concentrations

Continuous automatic monitors measured nitrogen dioxide concentrations at nine locations (Fig. 7) in Leicester during 2011. Leicester City Council do not routinely carry out monitoring by passive diffusion tube. Table 10 shows the measured concentrations at the automatic monitoring sites. Table 10 also shows the nearest DfT count points used in the source apportionment.

The source apportionment of measured nitrogen dioxide concentrations was carried out using Defra's NO_x to NO_2 converter. The NO_x to NO_2 converter calculates roadside nitrogen dioxide concentrations. It requires information on the contribution from vehicles to roadside oxides of nitrogen concentrations ($RoadNO_x$), the background oxides of nitrogen concentration (Back NO_x) and the proportion of oxides of nitrogen emitted from vehicles as primary nitrogen dioxide (fNO_2). The user selects the year and local authority and the tool provides appropriate estimates of regional background pollutant concentrations.

Defra provides mapped background concentrations on a 1 km x 1 km grid. The background maps show the contribution from the main sources of emission to background concentrations. For roadside sites (i.e. excluding the AURN site), the contributions from primary roads within the relevant 1 km squares were removed from the background totals. The mapped background concentrations were then scaled by a factor of 0.7 to provide good agreement with the measured nitrogen dioxide concentration at the Leicester AURN site. Table 10 shows the assumed background concentration of oxides of nitrogen at each of the monitoring sites.

Table 10: Measured concentrations at automatic monitoring sites, 2011

Site	Measured concentration, µg m^{-3}	Count point	Background oxides of nitrogen concentration, µg m^{-3}
Leicester AURN	30	Urban background site	45
Abbey Lane	45	57779	30
Glenhills Way	60	8585	24
Imperial Avenue	35	48777	31
London Road	27	26166	28
Melton Road	46	99342	35
St Matthews Way	55	36524	42
Uppingham Road	32	26515	33
Vaughan Way	73	56464	39

The NO_x to NO_2 converter requires an estimate of the fraction of oxides of nitrogen emitted from vehicles as primary nitrogen dioxide. The primary nitrogen factor (fNO_2) for each road link was calculated from the emissions for each road link.

The contribution from road vehicles ($RoadNO_x$) was estimated iteratively for the base 2011 case using the NO_x to NO_2 converter. Values of $RoadNO_x$ were adjusted to provide good agreement with the measured concentrations. We then reduced the $RoadNO_x$ value by removing the proportion of vehicle oxides of nitrogen emissions from each vehicle type in turn and using the converter to calculate the consequent nitrogen dioxide concentration. We adjusted the fNO_2 values to take account of the revised traffic mix. The first estimate of the contribution from each vehicle type was obtained by subtraction. Finally, the contributions were rescaled so that the total equalled the measured concentrations. The resulting source apportionment is shown in Table 11 and Fig. 16.

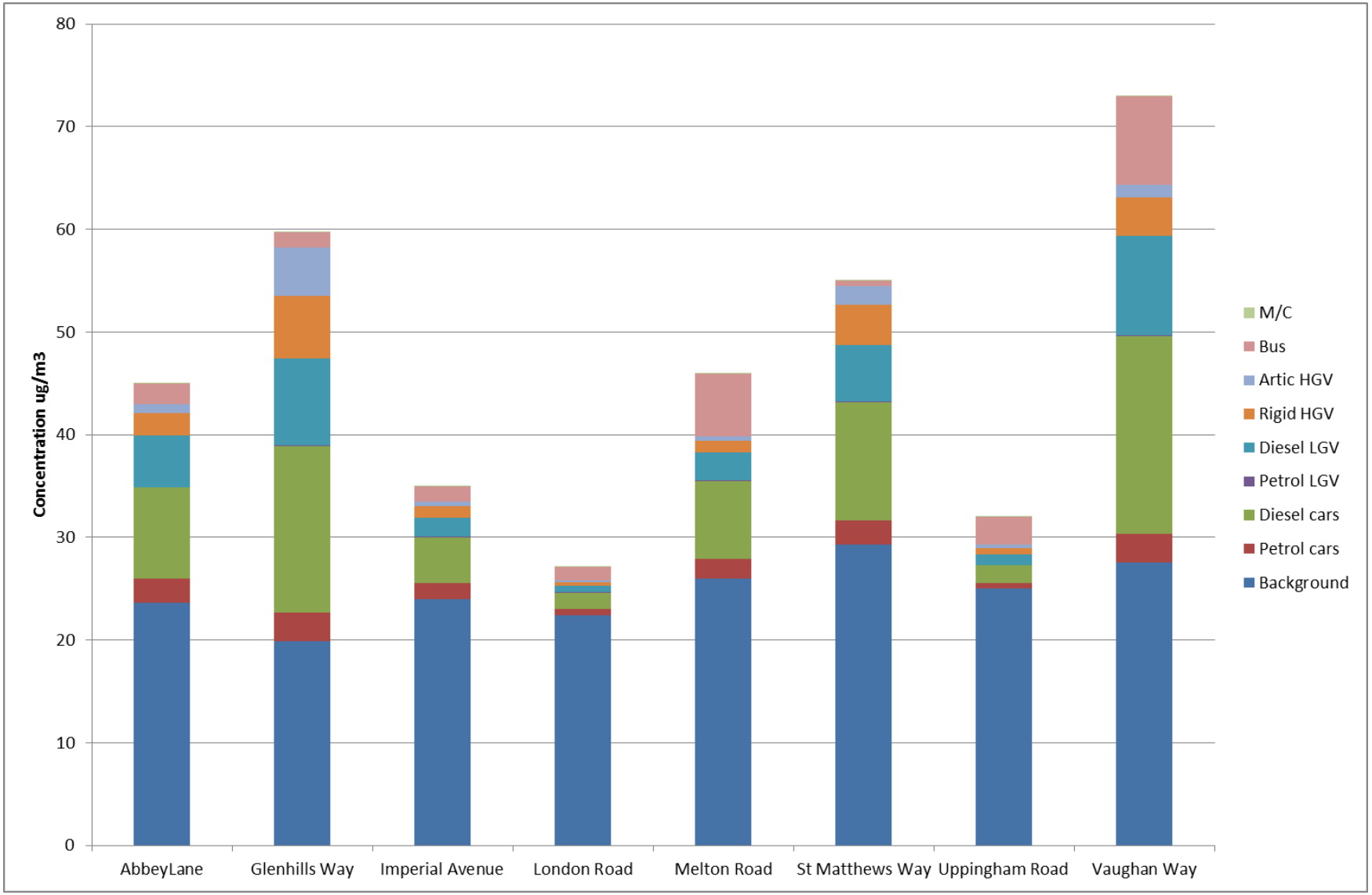
Background concentrations (e.g. from domestic, commercial, industrial sources and other sources throughout the UK and Europe) make the largest contribution, followed by diesel cars. Diesel light goods vehicles also make a substantial contribution at most locations. Heavy goods vehicles make a notable contribution on Gledhills Way on the outer ring road. Buses make a notable contribution on Melton Road and on Vaughan Way (inner ring road).

Concentrations measured on Imperial Road, London Road and Uppingham Road were less than the limit value of 40 µg m^{-3}. These are all radial roads:

Table 11: Source apportionment of measured NO_2 concentrations, µg m^{-3}

	Back-ground	Petrol cars	Diesel cars	Petrol LGV	Diesel LGV	Rigid HGV	Artic HGV	Bus	M/C
Abbey Lane	23.6	2.4	8.8	0.1	5.0	2.2	0.9	2.0	0.0
Glenhills Way	19.9	2.8	16.2	0.1	8.5	6.1	4.7	1.5	0.0
Imperial Avenue	24.0	1.5	4.5	0.0	1.9	1.2	0.4	1.5	0.0
London Road	22.4	0.6	1.6	0.0	0.6	0.4	0.2	1.3	0.0
Melton Road	26.0	1.9	7.6	0.0	2.7	1.1	0.4	6.2	0.0
St Matthews Way	29.3	2.4	11.5	0.1	5.5	3.9	1.8	0.5	0.0
Uppingham Road	25.0	0.5	1.7	0.0	1.0	0.7	0.3	2.7	0.0
Vaughan Way	27.5	2.8	19.3	0.1	9.7	3.7	1.2	8.7	0.0

Fig. 16: Source apportionment of measured nitrogen dioxide concentrations



3.2 Forecast concentrations at monitoring sites

The Emission Factor Toolkit was run for 2016 for each of the road links containing the monitoring sites. The 2011 traffic flows on each road link were scaled by a factor of 1.0556 obtained from the National Trip End Forecast model adjusted using the Tempro 6 model for Leicester. The proportion of each vehicle type (e.g. car, LGV, HGV, bus) was assumed to remain the same. The proportion of vehicles meeting the various Euro standards was adjusted according to the fleet mix incorporated within the Emission Factor Toolkit.

The Emission Factor Toolkit provided emission rates (g/km) for each road link. The contribution from road vehicles ($RoadNO_x$) to roadside oxides of nitrogen concentrations was estimated by scaling the 2011 values (3.1.5) by the ratio of the 2016 and 2011 emission rates.

The nitrogen dioxide concentration at each of the monitoring sites for 2016 was then estimated using the NO_x to NO_2 converter. Estimates of background oxides of nitrogen used in the converter were obtained from Defra's background maps for 2016: these were adjusted using a factor of 0.7 as described in 3.1.5.

Table 12 shows the forecast nitrogen dioxide concentrations for 2016 for the business as usual case. It also shows the forecast concentrations for two example LEZs for 2016: a basic LEZ with buses and HGVs required to meet the Euro IV standard and an Ultra LEZ with buses and HGVs required to meet the Euro VI standard.

Table 12: Forecast nitrogen dioxide concentrations, µg m^{-3}

Site	2011	2016 Business as usual	2016 LEZ	2016 Ultra LEZ
AbbeyLane	45.0	36.4	36.1	33.9
Glenhills Way	59.8	48.3	47.9	43.0
Imperial Avenue	35.0	28.2	28.0	26.6
London Road	27.1	22.0	21.9	21.0
Melton Road	46.0	37.7	37.0	33.2
St Matthews Way	55.0	45.5	45.3	42.8
Uppingham Road	32.0	25.9	25.6	23.8
Vaughan Way	73.0	60.5	59.6	53.3
Glenhills Way 2	59.8	47.8	47.5	43.9
AURN	30.7	25.2	25.2	25.2

Appendix 1 – Emission factors for 2011 by Euro class

Table A1.1: Oxides of nitrogen emission factors ,g km^{-1}

Vehicle	Euro class	Speed, kph												
		5	10	20	30	40	50	60	70	80	90	100	110	120
Petrol car	2011 mix	0.220	0.211	0.195	0.177	0.164	0.157	0.155	0.158	0.165	0.173	0.185	0.201	0.223
	pre-Euro	1.596	1.596	1.678	1.781	1.905	2.050	2.216	2.402	2.610	2.839	3.089	3.360	3.652
	Euro 1	1.016	0.925	0.769	0.635	0.545	0.496	0.484	0.518	0.592	0.700	0.843	1.019	1.230
	Euro 2	0.577	0.545	0.464	0.369	0.303	0.273	0.267	0.278	0.295	0.312	0.327	0.341	0.352
	Euro 3	0.111	0.109	0.103	0.093	0.084	0.074	0.065	0.059	0.054	0.051	0.051	0.057	0.074
	Euro 4	0.107	0.099	0.084	0.070	0.057	0.046	0.037	0.030	0.025	0.021	0.019	0.018	0.019
	Euro 5	0.074	0.068	0.058	0.049	0.041	0.034	0.028	0.023	0.019	0.016	0.014	0.014	0.014
	Euro 6	0.074	0.068	0.058	0.049	0.041	0.034	0.028	0.023	0.019	0.016	0.014	0.014	0.014
Diesel car	2011 mix	0.970	0.970	0.769	0.646	0.563	0.509	0.480	0.474	0.491	0.531	0.596	0.692	0.831
	pre-Euro	0.915	0.915	0.794	0.696	0.620	0.567	0.536	0.528	0.542	0.579	0.638	0.719	0.823
	Euro 1	1.321	1.321	0.879	0.698	0.612	0.573	0.562	0.570	0.592	0.627	0.673	0.730	0.799
	Euro 2	1.355	1.355	0.962	0.768	0.660	0.599	0.569	0.563	0.577	0.612	0.674	0.771	0.923
	Euro 3[a]	1.216	1.216	0.907	0.781	0.718	0.685	0.669	0.667	0.678	0.704	0.751	0.835	1.000
	Euro 4[b]	0.921	0.921	0.764	0.637	0.539	0.471	0.433	0.424	0.445	0.496	0.576	0.686	0.826
	Euro 5	0.663	0.663	0.550	0.458	0.388	0.339	0.312	0.305	0.320	0.357	0.415	0.494	0.595
	Euro 6	0.295	0.295	0.245	0.204	0.172	0.151	0.138	0.136	0.142	0.159	0.184	0.220	0.264
LGV	2011 mix	1.204	1.204	1.032	0.895	0.793	0.724	0.688	0.685	0.715	0.779	0.876	1.006	1.016
	pre-Euro	3.803	3.803	2.937	2.223	1.659	1.246	0.983	0.872	0.911	1.101	1.442	1.934	1.940
	Euro 1	1.709	1.709	1.452	1.255	1.109	1.012	0.961	0.957	1.000	1.089	1.223	1.403	1.413
	Euro 2	1.683	1.682	1.432	1.237	1.093	0.995	0.945	0.940	0.981	1.068	1.201	1.380	1.391
	Euro 3	1.397	1.397	1.191	1.032	0.913	0.834	0.792	0.788	0.822	0.894	1.003	1.152	1.162
	Euro 4	1.121	1.121	0.960	0.831	0.733	0.667	0.632	0.628	0.656	0.716	0.806	0.929	0.937
	Euro 5	0.807	0.807	0.692	0.599	0.528	0.480	0.455	0.453	0.473	0.516	0.581	0.669	0.675
	Euro 6	0.363	0.363	0.311	0.269	0.238	0.216	0.205	0.204	0.213	0.232	0.261	0.301	0.304

Vehicle	Euro class	Speed, kph												
		5	10	20	30	40	50	60	70	80	90	100	110	120
Rigid HGV	2011 mix	9.662	9.662	6.980	5.359	4.473	3.938	3.598	3.370	3.205	3.121	3.121	3.121	3.121
	pre-Euro	16.239	16.239	12.379	10.237	9.132	8.495	8.119	7.909	7.817	7.806	7.806	7.806	7.806
	Euro I	11.428	11.428	8.630	7.053	6.254	5.812	5.566	5.442	5.401	5.408	5.408	5.408	5.408
	Euro II	12.625	12.625	9.438	7.692	6.796	6.279	5.971	5.795	5.712	5.696	5.696	5.696	5.696
	Euro III	10.962	10.962	7.860	6.195	5.374	4.916	4.648	4.492	4.412	4.391	4.391	4.391	4.391
	Euro IV	6.651	6.651	5.109	4.164	3.685	3.443	3.323	3.251	3.166	3.087	3.087	3.087	3.087
	Euro V[c]	9.830	9.830	6.847	4.776	3.502	2.647	2.044	1.600	1.257	1.083	1.083	1.083	1.083
	Euro VI	2.253	2.253	1.139	0.638	0.411	0.287	0.211	0.161	0.127	0.111	0.111	0.111	0.111
Artic HGV	2011 mix	15.089	15.089	10.698	7.869	6.254	5.249	4.586	4.108	3.711	3.477	3.477	3.477	3.477
	pre-Euro	26.654	26.654	21.034	17.366	15.146	13.622	12.494	11.618	10.912	10.549	10.549	10.549	10.549
	Euro I	19.341	19.341	14.957	12.231	10.630	9.553	8.769	8.167	7.689	7.445	7.445	7.445	7.445
	Euro II	21.250	21.250	16.195	13.118	11.342	10.164	9.316	8.673	8.167	7.912	7.912	7.912	7.912
	Euro III	17.788	17.788	13.279	10.621	9.127	8.158	7.476	6.969	6.579	6.385	6.385	6.385	6.385
	Euro IV	11.077	11.077	8.860	7.208	6.231	5.662	5.318	5.044	4.695	4.392	4.392	4.392	4.392
	Euro V[c]	15.893	15.893	10.415	6.896	4.894	3.647	2.827	2.259	1.837	1.623	1.623	1.623	1.623
	Euro VI	3.032	3.032	1.306	0.719	0.485	0.362	0.287	0.237	0.201	0.184	0.184	0.184	0.184
Bus and coach	2011 mix	15.721	15.721	10.167	7.472	6.033	5.160	4.600	4.223	3.949	3.784	3.737	3.719	3.719
	pre-Euro	23.162	23.162	16.601	13.370	11.658	10.617	9.937	9.479	9.169	9.014	8.980	8.971	8.971
	Euro I	16.495	16.495	11.435	9.098	7.865	7.093	6.562	6.175	5.882	5.722	5.693	5.685	5.685
	Euro II	18.390	18.390	12.672	9.955	8.536	7.662	7.073	6.652	6.340	6.168	6.127	6.113	6.113
	Euro III	19.007	19.007	11.549	8.451	6.905	5.969	5.339	4.887	4.548	4.363	4.327	4.315	4.315
	Euro IV	10.093	10.093	7.029	5.495	4.661	4.134	3.771	3.505	3.301	3.188	3.165	3.156	3.156
	Euro V[c]	13.224	13.224	8.830	5.941	4.227	3.212	2.636	2.317	2.109	1.942	1.858	1.823	1.823
	Euro VI	2.469	2.469	1.130	0.638	0.426	0.313	0.245	0.200	0.170	0.151	0.142	0.138	0.138
motorcycle	2011 mix	0.180	0.159	0.133	0.126	0.132	0.149	0.174	0.207	0.246	0.292	0.342	0.393	0.456

Notes: a)16% of Euro 3 diesel cars fitted with diesel particle filters. b) 20% of Euro 4 diesel cars fitted with diesel particle filters. c) 25% fitted with Exhaust Gas Recirculation and 75% with Selective Catalytic Reduction

Table A1.2: PM_{10} emission factors ,g km^{-1}

Vehicle	Euro class	Speed, kph												
		5	10	20	30	40	50	60	70	80	90	100	110	120
Petrol car	2011 mix	0.035	0.032	0.030	0.030	0.030	0.030	0.030	0.030	0.031	0.031	0.032	0.032	0.033
	pre-Euro	0.038	0.034	0.032	0.031	0.031	0.032	0.032	0.032	0.033	0.034	0.035	0.037	0.038
	Euro 1	0.036	0.033	0.031	0.031	0.030	0.031	0.031	0.031	0.032	0.032	0.033	0.034	0.035
	Euro 2	0.034	0.032	0.030	0.030	0.030	0.030	0.030	0.030	0.031	0.031	0.032	0.032	0.033
	Euro 3	0.034	0.032	0.030	0.030	0.030	0.030	0.030	0.030	0.031	0.031	0.032	0.032	0.033
	Euro 4	0.034	0.032	0.030	0.030	0.030	0.030	0.030	0.030	0.031	0.031	0.032	0.032	0.033
	Euro 5	0.034	0.032	0.030	0.030	0.030	0.030	0.030	0.030	0.031	0.031	0.032	0.032	0.033
	Euro 6	0.034	0.032	0.030	0.030	0.030	0.030	0.030	0.030	0.031	0.031	0.032	0.032	0.033
Diesel car	2011 mix	0.083	0.060	0.049	0.047	0.045	0.045	0.045	0.046	0.047	0.048	0.049	0.051	0.053
	pre-Euro	0.751	0.422	0.262	0.212	0.190	0.179	0.175	0.176	0.180	0.188	0.202	0.222	0.252
	Euro 1	0.323	0.180	0.109	0.087	0.077	0.072	0.071	0.071	0.074	0.080	0.088	0.102	0.121
	Euro 2	0.138	0.090	0.067	0.061	0.059	0.060	0.062	0.065	0.069	0.074	0.081	0.089	0.100
	Euro 3[a]	0.112	0.077	0.061	0.056	0.054	0.054	0.054	0.054	0.056	0.057	0.058	0.060	0.063
	Euro 4[b]	0.079	0.059	0.049	0.047	0.046	0.046	0.046	0.046	0.047	0.048	0.050	0.051	0.053
	Euro 5	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
	Euro 6	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
LGV	2011 mix	0.192	0.119	0.083	0.072	0.067	0.066	0.066	0.067	0.070	0.074	0.081	0.091	0.105
	pre-Euro	1.228	0.679	0.409	0.324	0.285	0.265	0.254	0.250	0.251	0.254	0.261	0.270	0.281
	Euro 1	0.344	0.205	0.137	0.118	0.111	0.110	0.113	0.119	0.128	0.140	0.156	0.176	0.202
	Euro 2	0.205	0.144	0.116	0.109	0.108	0.109	0.112	0.115	0.120	0.126	0.132	0.140	0.148
	Euro 3	0.258	0.152	0.100	0.084	0.076	0.074	0.073	0.075	0.079	0.086	0.096	0.110	0.131
	Euro 4	0.186	0.115	0.080	0.069	0.064	0.062	0.062	0.063	0.066	0.070	0.077	0.086	0.100
	Euro 5	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
	Euro 6	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040

Vehicle	Euro class	Speed, kph												
		5	10	20	30	40	50	60	70	80	90	100	110	120
Rigid HGV	2011 mix	0.370	0.304	0.232	0.197	0.179	0.169	0.164	0.164	0.166	0.169	0.169	0.169	0.169
	pre-Euro	1.985	1.452	0.963	0.742	0.616	0.546	0.517	0.515	0.527	0.540	0.540	0.540	0.540
	Euro I	1.292	0.945	0.614	0.470	0.392	0.350	0.333	0.331	0.338	0.345	0.345	0.345	0.345
	Euro II	0.407	0.369	0.305	0.263	0.235	0.220	0.215	0.218	0.229	0.247	0.247	0.247	0.247
	Euro III	0.578	0.465	0.334	0.270	0.236	0.217	0.209	0.208	0.211	0.214	0.214	0.214	0.214
	Euro IV	0.234	0.194	0.157	0.142	0.135	0.131	0.129	0.129	0.129	0.130	0.130	0.130	0.130
	Euro V[c]	0.236	0.195	0.158	0.143	0.135	0.131	0.129	0.129	0.130	0.130	0.130	0.130	0.130
	Euro VI	0.123	0.119	0.115	0.114	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113
Artic HGV	2011 mix	0.455	0.362	0.272	0.231	0.209	0.197	0.191	0.191	0.193	0.196	0.196	0.196	0.196
	pre-Euro	2.314	1.695	1.166	0.920	0.765	0.674	0.635	0.632	0.647	0.663	0.663	0.663	0.663
	Euro I	2.121	1.505	0.977	0.748	0.616	0.542	0.509	0.505	0.517	0.529	0.529	0.529	0.529
	Euro II	0.643	0.597	0.496	0.416	0.357	0.320	0.305	0.313	0.342	0.396	0.396	0.396	0.396
	Euro III	0.919	0.705	0.492	0.392	0.335	0.304	0.290	0.288	0.293	0.298	0.298	0.298	0.298
	Euro IV	0.319	0.261	0.205	0.182	0.171	0.164	0.161	0.161	0.162	0.163	0.163	0.163	0.163
	Euro V[c]	0.324	0.263	0.207	0.183	0.171	0.165	0.162	0.161	0.162	0.163	0.163	0.163	0.163
	Euro VI	0.153	0.147	0.141	0.139	0.138	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137
Bus and coach	2011 mix	0.491	0.380	0.276	0.231	0.206	0.191	0.183	0.178	0.175	0.174	0.173	0.173	0.173
	pre-Euro	2.375	1.662	0.999	0.731	0.591	0.509	0.459	0.430	0.418	0.414	0.412	0.411	0.411
	Euro I	1.316	1.001	0.670	0.518	0.434	0.382	0.349	0.326	0.314	0.311	0.309	0.308	0.308
	Euro II	0.546	0.455	0.340	0.282	0.251	0.234	0.224	0.218	0.215	0.214	0.213	0.213	0.213
	Euro III	0.631	0.482	0.347	0.284	0.248	0.227	0.216	0.208	0.203	0.201	0.200	0.199	0.199
	Euro IV	0.299	0.229	0.174	0.153	0.143	0.137	0.134	0.132	0.131	0.131	0.131	0.131	0.131
	Euro V[c]	0.304	0.232	0.175	0.154	0.144	0.138	0.135	0.133	0.132	0.132	0.131	0.131	0.131
	Euro VI	0.132	0.125	0.119	0.117	0.116	0.115	0.115	0.115	0.115	0.115	0.115	0.115	0.115
motorcycle	2011 mix	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028

Table A1.3: $PM_{2.5}$ emission factors ,g km^{-1}

Vehicle	Euro class	Speed, kph												
		5	10	20	30	40	50	60	70	80	90	100	110	120
Petrol car	2011 mix	0.021	0.018	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.018	0.019	0.020
	pre-Euro	0.025	0.021	0.019	0.018	0.018	0.018	0.019	0.019	0.020	0.021	0.022	0.023	0.025
	Euro 1	0.023	0.019	0.018	0.017	0.017	0.017	0.018	0.018	0.018	0.019	0.019	0.020	0.021
	Euro 2	0.021	0.018	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.019	0.020
	Euro 3	0.021	0.018	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.019	0.020
	Euro 4	0.021	0.018	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.019	0.020
	Euro 5	0.021	0.018	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.019	0.020
	Euro 6	0.021	0.018	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.018	0.019	0.020
Diesel car	2011 mix	0.067	0.045	0.035	0.032	0.031	0.031	0.031	0.032	0.033	0.034	0.035	0.037	0.039
	pre-Euro	0.701	0.389	0.237	0.190	0.169	0.159	0.155	0.155	0.160	0.167	0.180	0.199	0.228
	Euro 1	0.295	0.159	0.092	0.071	0.061	0.057	0.055	0.056	0.059	0.064	0.072	0.085	0.103
	Euro 2	0.120	0.074	0.052	0.046	0.045	0.045	0.047	0.050	0.054	0.059	0.065	0.073	0.083
	Euro 3[a]	0.095	0.062	0.046	0.041	0.040	0.039	0.039	0.040	0.041	0.042	0.044	0.046	0.048
	Euro 4[b]	0.063	0.044	0.035	0.033	0.032	0.032	0.032	0.032	0.033	0.034	0.035	0.037	0.039
	Euro 5	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
	Euro 6	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
LGV	2011 mix	0.166	0.096	0.063	0.052	0.048	0.046	0.046	0.047	0.050	0.054	0.061	0.070	0.083
	pre-Euro	1.150	0.629	0.372	0.291	0.254	0.235	0.225	0.221	0.222	0.225	0.231	0.239	0.250
	Euro 1	0.310	0.178	0.114	0.095	0.089	0.088	0.091	0.097	0.105	0.117	0.132	0.151	0.175
	Euro 2	0.178	0.120	0.094	0.087	0.086	0.087	0.090	0.093	0.098	0.103	0.109	0.116	0.124
	Euro 3	0.229	0.128	0.078	0.063	0.056	0.053	0.053	0.055	0.059	0.065	0.074	0.088	0.107
	Euro 4	0.160	0.092	0.059	0.049	0.044	0.042	0.042	0.043	0.046	0.050	0.056	0.065	0.078
	Euro 5	0.022	0.022	0.022	0.021	0.021	0.021	0.021	0.021	0.021	0.022	0.022	0.022	0.022
	Euro 6	0.022	0.022	0.022	0.021	0.021	0.021	0.021	0.021	0.021	0.022	0.022	0.022	0.022

Vehicle	Euro class	Speed, kph												
		5	10	20	30	40	50	60	70	80	90	100	110	120
Rigid HGV	2011 mix	0.303	0.240	0.171	0.138	0.121	0.111	0.107	0.107	0.109	0.112	0.112	0.112	0.112
	pre-Euro	1.837	1.331	0.866	0.656	0.536	0.470	0.442	0.440	0.452	0.464	0.464	0.464	0.464
	Euro I	1.178	0.849	0.535	0.397	0.323	0.284	0.267	0.265	0.272	0.279	0.279	0.279	0.279
	Euro II	0.337	0.301	0.241	0.201	0.175	0.160	0.155	0.158	0.168	0.186	0.186	0.186	0.186
	Euro III	0.500	0.393	0.269	0.208	0.175	0.157	0.149	0.148	0.151	0.154	0.154	0.154	0.154
	Euro IV	0.173	0.135	0.100	0.086	0.079	0.075	0.074	0.073	0.074	0.074	0.074	0.074	0.074
	Euro V[c]	0.176	0.137	0.101	0.086	0.079	0.076	0.074	0.073	0.074	0.075	0.075	0.075	0.075
	Euro VI	0.068	0.064	0.061	0.059	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058
Artic HGV	2011 mix	0.377	0.289	0.203	0.165	0.144	0.132	0.127	0.126	0.128	0.131	0.131	0.131	0.131
	pre-Euro	2.144	1.555	1.053	0.819	0.672	0.586	0.548	0.545	0.560	0.575	0.575	0.575	0.575
	Euro I	1.960	1.375	0.873	0.656	0.531	0.460	0.429	0.425	0.436	0.448	0.448	0.448	0.448
	Euro II	0.556	0.512	0.416	0.340	0.285	0.249	0.235	0.242	0.270	0.321	0.321	0.321	0.321
	Euro III	0.818	0.615	0.412	0.317	0.263	0.234	0.221	0.219	0.223	0.229	0.229	0.229	0.229
	Euro IV	0.249	0.193	0.140	0.118	0.107	0.101	0.098	0.098	0.099	0.100	0.100	0.100	0.100
	Euro V[c]	0.253	0.195	0.141	0.119	0.108	0.102	0.099	0.098	0.099	0.100	0.100	0.100	0.100
	Euro VI	0.091	0.085	0.079	0.077	0.076	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075
Bus and coach	2011 mix	0.416	0.310	0.212	0.169	0.145	0.131	0.124	0.119	0.116	0.115	0.114	0.114	0.114
	pre-Euro	2.206	1.529	0.899	0.644	0.511	0.433	0.386	0.358	0.346	0.343	0.341	0.340	0.340
	Euro I	1.200	0.901	0.586	0.441	0.361	0.313	0.281	0.259	0.248	0.245	0.243	0.242	0.242
	Euro II	0.469	0.382	0.272	0.218	0.188	0.171	0.162	0.157	0.154	0.153	0.152	0.152	0.152
	Euro III	0.549	0.408	0.279	0.219	0.185	0.166	0.155	0.147	0.143	0.141	0.139	0.139	0.139
	Euro IV	0.234	0.168	0.114	0.095	0.085	0.080	0.077	0.075	0.074	0.074	0.074	0.074	0.074
	Euro V[c]	0.238	0.170	0.116	0.096	0.086	0.081	0.077	0.076	0.075	0.075	0.074	0.074	0.074
	Euro VI	0.075	0.068	0.063	0.061	0.060	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
motorcycle	2011 mix	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021

Table A1.4: CO2 emission factors ,g km^{-1}

Vehicle	Euro class	Speed, kph												
		5	10	20	30	40	50	60	70	80	90	100	110	120
Petrol car	2011 mix	614.4	356.0	226.9	184.9	165.5	155.8	151.5	150.9	152.8	157.0	163.0	170.6	179.7
	pre-Euro	654.7	396.3	267.2	225.2	205.8	196.1	191.8	191.2	193.1	197.3	203.3	210.9	220.0
	Euro 1	639.5	381.1	252.0	210.0	190.6	180.9	176.6	176.0	177.9	182.1	188.1	195.7	204.8
	Euro 2	631.5	373.2	244.1	202.0	182.6	172.9	168.7	168.0	170.0	174.1	180.1	187.7	196.9
	Euro 3	619.8	361.4	232.3	190.3	170.9	161.2	156.9	156.2	158.2	162.4	168.3	176.0	185.1
	Euro 4	607.0	348.6	219.5	177.5	158.1	148.4	144.1	143.5	145.4	149.6	155.5	163.2	172.3
	Euro 5	588.6	330.3	201.2	159.1	139.7	130.0	125.8	125.1	127.1	131.2	137.2	144.8	154.0
	Euro 6	573.1	314.8	185.7	143.7	124.2	114.6	110.3	109.6	111.6	115.7	121.7	129.3	138.5
Diesel car	2011 mix	413.2	276.4	199.6	168.5	150.6	139.6	133.1	130.4	130.9	134.3	140.6	149.6	161.2
	pre-Euro	452.0	315.3	238.4	207.3	189.5	178.4	172.0	169.2	169.7	173.2	179.4	188.4	200.0
	Euro 1	446.5	309.7	232.9	201.8	183.9	172.9	166.4	163.7	164.2	167.6	173.9	182.9	194.5
	Euro 2	435.4	298.6	221.8	190.7	172.8	161.8	155.3	152.6	153.1	156.5	162.8	171.8	183.4
	Euro 3[a]	421.0	284.2	207.4	176.3	158.4	147.4	140.9	138.2	138.7	142.1	148.4	157.4	169.0
	Euro 4[b]	413.5	276.8	199.9	168.8	151.0	139.9	133.5	130.7	131.2	134.7	140.9	149.9	161.5
	Euro 5	396.0	259.2	182.3	151.2	133.4	122.3	115.9	113.2	113.6	117.1	123.4	132.3	144.0
	Euro 6	381.1	244.3	167.4	136.3	118.5	107.4	101.0	98.3	98.7	102.2	108.5	117.4	129.1
LGV	2011 mix	831.0	452.0	267.7	212.6	191.4	185.2	187.9	197.3	212.7	234.2	262.2	297.4	341.0
	pre-Euro	677.9	386.7	248.1	208.5	194.6	191.8	195.7	204.5	217.4	234.4	255.3	280.4	309.8
	Euro 1	770.2	439.6	281.1	235.4	218.9	215.3	219.1	228.5	242.5	261.0	284.2	312.2	345.6
	Euro 2	837.5	462.3	281.7	228.5	208.2	202.3	204.8	213.4	227.5	246.8	271.6	302.0	338.7
	Euro 3	831.5	452.0	267.3	212.0	190.7	184.4	187.1	196.5	212.0	233.5	261.6	297.0	341.0
	Euro 4	831.3	451.7	267.0	211.7	190.4	184.1	186.7	196.2	211.6	233.1	261.3	296.7	340.6
	Euro 5	830.7	451.0	266.2	210.8	189.5	183.2	185.8	195.3	210.7	232.2	260.4	295.8	339.8
	Euro 6	830.3	450.4	265.5	210.1	188.7	182.4	185.1	194.5	209.9	231.5	259.6	295.1	339.0

Vehicle	Euro class	Speed, kph												
		5	10	20	30	40	50	60	70	80	90	100	110	120
Rigid HGV	2011 mix	1571.2	1205.4	893.1	738.0	636.7	578.5	557.2	562.9	584.1	612.0	612.0	612.0	612.0
	pre-Euro	2121.2	1552.2	1106.0	898.5	763.7	686.6	658.3	664.1	688.2	721.6	721.6	721.6	721.6
	Euro I	1669.5	1263.0	923.9	760.9	655.7	595.8	574.3	581.0	603.7	632.6	632.6	632.6	632.6
	Euro II	1467.1	1170.0	880.9	729.7	633.6	579.4	559.5	565.5	588.0	619.3	619.3	619.3	619.3
	Euro III	1569.8	1232.6	922.7	763.0	659.5	600.2	578.1	583.7	605.8	634.2	634.2	634.2	634.2
	Euro IV	1569.9	1178.6	865.9	715.9	616.9	559.8	539.2	545.1	565.6	592.4	592.4	592.4	592.4
	Euro V[c]	1600.2	1205.1	884.6	729.7	627.7	568.9	547.5	553.1	573.6	600.7	600.7	600.7	600.7
	Euro VI	1600.2	1205.1	884.6	729.7	627.7	568.9	547.5	553.1	573.6	600.7	600.7	600.7	600.7
Artic HGV	2011 mix	2597.2	1942.2	1502.3	1265.6	1071.0	939.4	880.2	878.3	904.6	930.6	930.6	930.6	930.6
	pre-Euro	3289.2	2406.7	1811.8	1507.9	1267.5	1109.2	1040.3	1039.6	1070.7	1100.5	1100.5	1100.5	1100.5
	Euro I	2895.7	2076.1	1573.3	1325.2	1119.9	981.7	921.9	922.4	949.8	975.5	975.5	975.5	975.5
	Euro II	2713.0	1957.1	1512.9	1290.9	1099.1	966.7	908.2	908.2	935.1	960.8	960.8	960.8	960.8
	Euro III	2674.5	2023.8	1573.4	1325.6	1123.1	986.6	925.2	923.2	950.8	978.3	978.3	978.3	978.3
	Euro IV	2536.5	1891.0	1462.6	1233.6	1044.4	916.2	858.6	856.9	882.5	907.7	907.7	907.7	907.7
	Euro V[c]	2593.3	1934.4	1492.9	1256.5	1062.3	930.9	871.7	869.8	895.9	921.5	921.5	921.5	921.5
	Euro VI	2593.3	1934.4	1492.9	1256.5	1062.3	930.9	871.7	869.8	895.9	921.5	921.5	921.5	921.5
Bus and coach	2011 mix	2838.8	1883.7	1138.3	873.0	737.9	663.0	624.9	613.8	618.8	630.3	650.8	664.3	664.3
	pre-Euro	3271.8	2187.9	1331.4	1019.0	856.2	764.2	716.5	702.1	708.1	721.1	744.1	759.2	759.2
	Euro I	2689.1	1824.2	1133.5	876.6	740.6	663.0	622.9	611.4	617.1	628.3	648.3	661.5	661.5
	Euro II	2326.5	1647.1	1082.9	857.9	731.9	656.9	616.7	604.5	610.0	620.9	640.3	653.2	653.2
	Euro III	3060.3	1990.0	1170.5	890.0	752.5	678.6	642.0	631.4	636.2	648.0	669.1	683.1	683.1
	Euro IV	2683.6	1802.1	1104.3	849.1	716.0	641.0	602.7	591.9	597.5	608.6	628.4	641.5	641.5
	Euro V[c]	2873.0	1897.5	1137.8	868.4	731.7	655.9	617.4	605.7	610.5	622.0	642.5	656.0	656.0
	Euro VI	2873.0	1897.5	1137.8	868.4	731.7	655.9	617.4	605.7	610.5	622.0	642.5	656.0	656.0
motorcycle	2011 mix	220.2	182.9	133.9	108.0	95.9	91.5	91.1	93.0	96.8	102.7	110.8	120.2	132.2

RICARDO-AEA

The Gemini Building
Fermi Avenue
Harwell
Didcot
Oxfordshire
OX11 0QR

Tel: 01235 75 3000
Web: www.ricardo-aea.com