Informing current and future local air quality management in Ealing: The case of NO_x emissions from road transport

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APRIL Transport sub-group, October 12th 2015

Background

- Objective: To develop future year policy scenarios to inform local air quality management in Ealing;
- Based on the extensive NO_2 and NO data sets collected using remote sensing instrumentation in the summer of 2012;
- Data provides detailed insights into the NO_2 and NO emission characteristics of vehicle types, ‘Euro’ classes, and fuel technologies at 2012;
- Data allows us to describe to some extent the more detailed dynamic relationships between NO_2 and NO emissions and engine load (function of vehicle speed, acceleration, vehicle mass, highway gradient…..);

Overview (1)

- Define the relationship between light vehicle highway traffic and primary NO_2 and NO exhaust emissions on representative samples of the road network in Ealing (**case study areas**);
- Quantify the emissions contribution of light vehicle traffic on these road types, taking into account **local traffic volume**, variation in **local fleet composition**, and variation in local traffic **operating conditions** during representative weekdays.

Overview (2)

- A simplified approach is adopted for heavy goods vehicles and buses, utilising mean emission rates (where available) by technology type / Euro standard, combined with estimates of fuel consumption rates and distance travelled in the case study areas;
- Develop illustrative future year scenario definitions and assumptions for light and heavy vehicles;
- Estimate impact of changes in future fleet composition, emission rates, and scenario interventions on future air quality in the case study areas.

Project partners

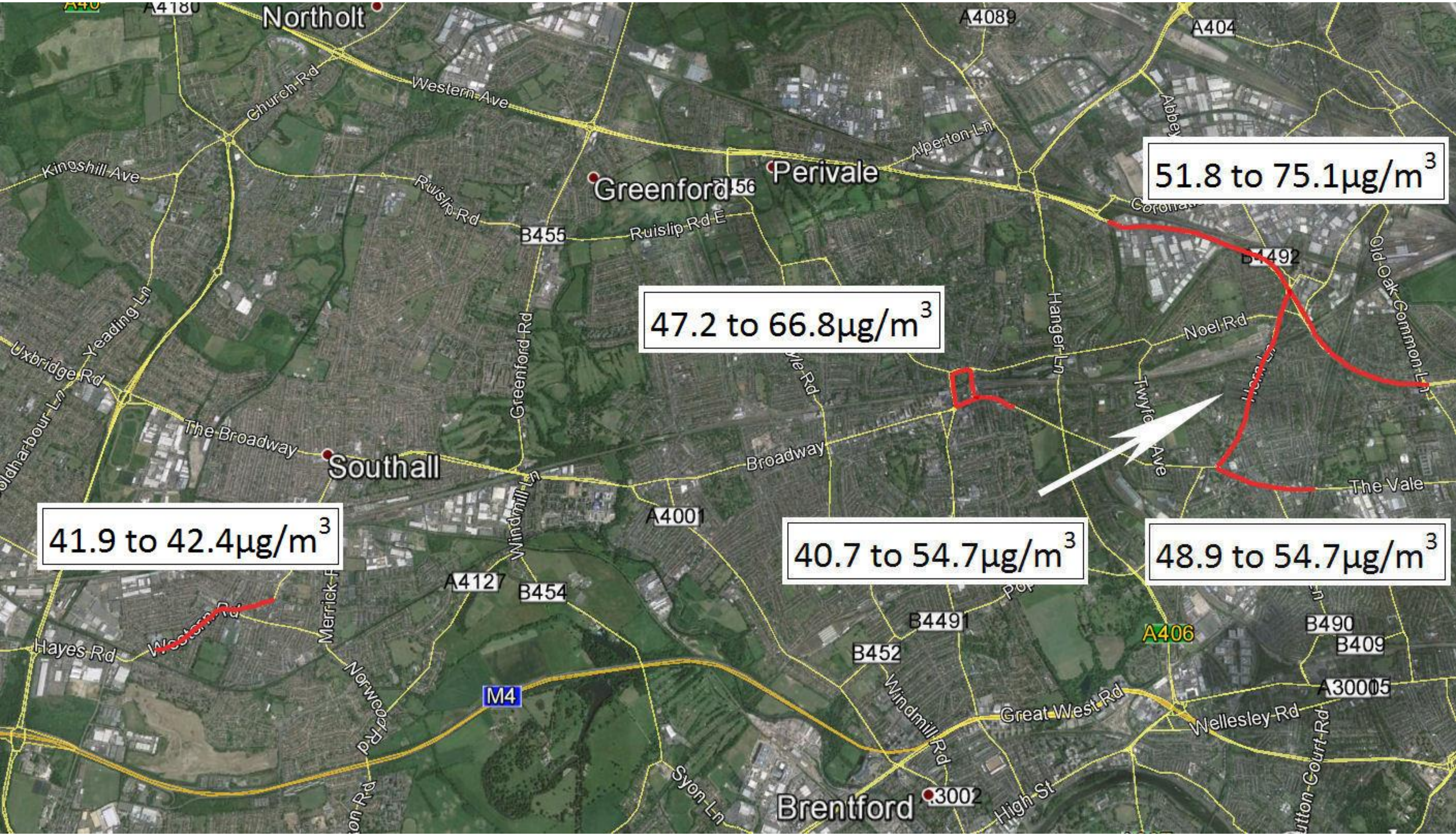
Ealing
www.ealing.gov.uk

Department
for Environment
Food & Rural Affairs

Conceptual principles

- **Emission rate** – Originally measured as molar ratios of pollutant to carbon dioxide i.e. NO_2/CO_2 and NO/CO_2. Converted into ratios of grams of pollutant per kilogram of fuel burned (g/kg) by carbon balance;
- **Fuel consumption rate** - grams per second derived from published type approval (NEDC) data;
- **Elapsed time on network** – For light vehicles, derived from multiple probe vehicle survey data;
- **Traffic volume** - by each sub-group for which observed emission rates are available e.g. passenger cars by fuel type, engine capacity (COPERT classifications), and Euro standard. Diesel vans by Euro standard.

Case study areas



Annual mean NO_2 concentration (2012 diffusion tube data)

Case study areas

Acton High Street

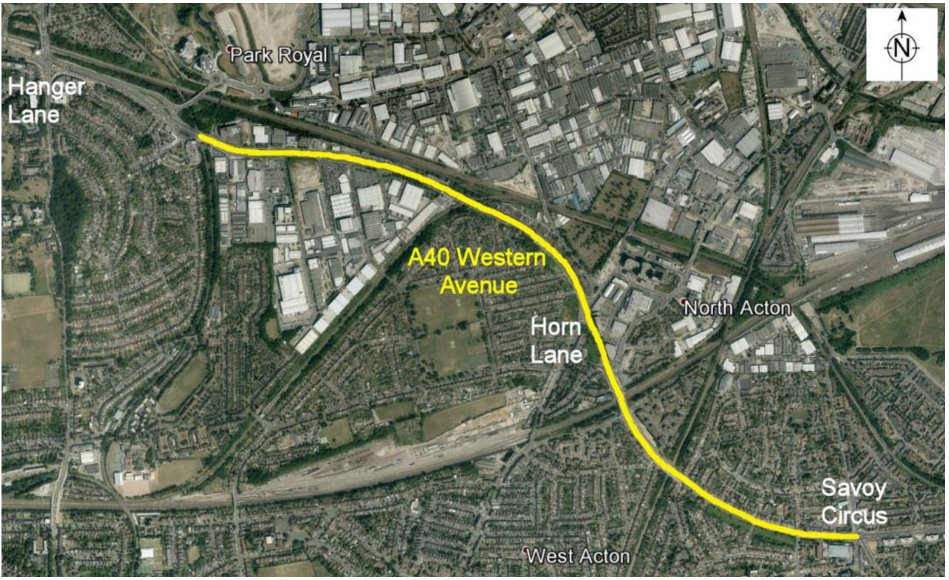
Horn Lane

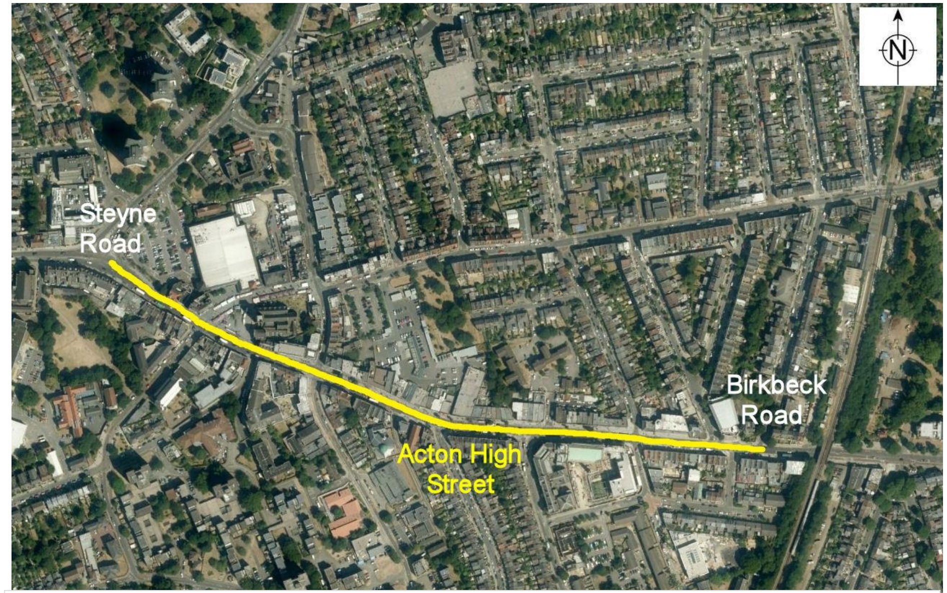
Haven Green

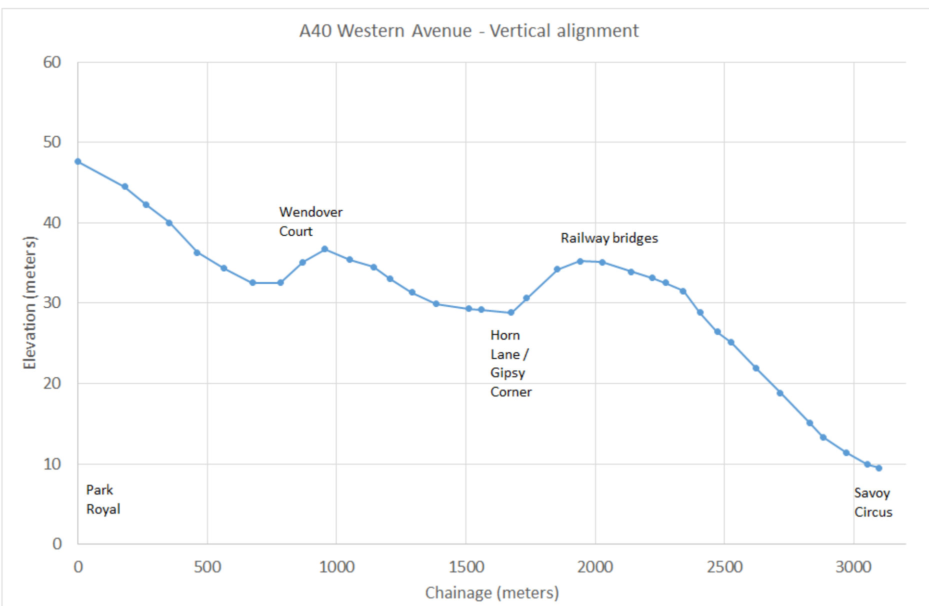
A40 Western Avenue

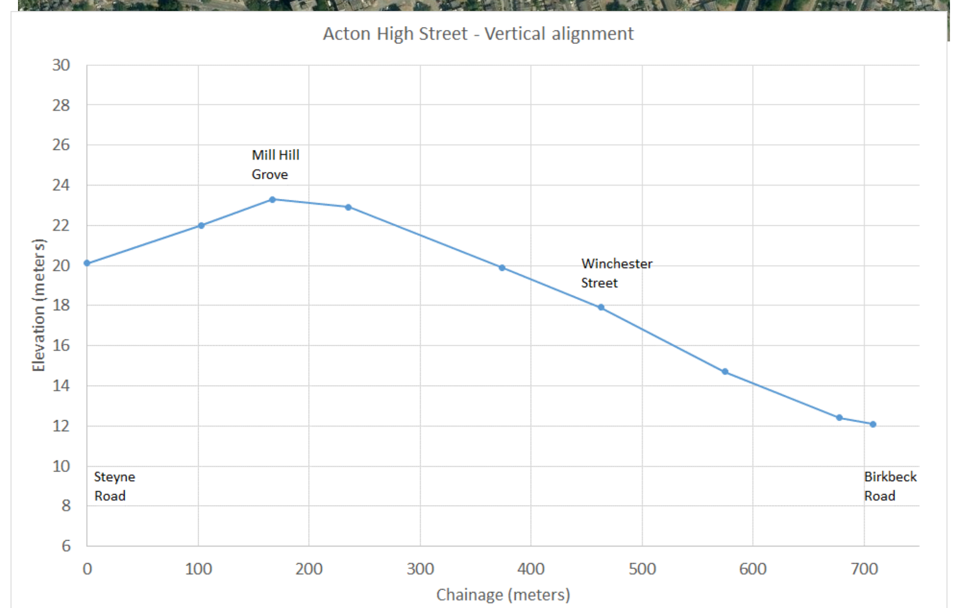
Western Road

Significance of gradient









Probe vehicle surveys

Collecting data on the dynamics of light vehicle operation (speed, acceleration, deceleration, stops) within the case study areas (using a GPS equipped probe vehicle at 10Hz). Two main objectives;

- Quantifying spatial variation in vehicle dynamics, and;
- Variability in vehicle speeds and delays across multiple journeys. Aimed to obtain 30+ runs by direction.

Generally between 0900 and 1800 weekdays.

Probe vehicle survey summary statistics

Location	Distance (km)	Mean journey time (seconds)	Mean speed (kph)	Mean % journey time spent stationary	% Journey time spent stationary >10 seconds	Percentage of journey time where speed >20mph
Acton High Street (E/B)	0.712	164.6	15	19%	10%	5%
Acton High Street (W/B)	0.712	289.1	9	35%	22%	1%
Horn Lane (N/B)	1.448	316.1	16	29%	25%	20%
Horn Lane (S/B)	1.283	185.5	24	13%	10%	34%
A40 (E/B) [b]	3.100	387.8	29	30%	27%	36% [a]
A40 (W/B)	3.100	296.9	37	8%	6%	40% [a]
The Mall (W/B)	0.297	90.2	12	35%	27%	11%
Haven Green Loop (clockwise)	0.931	230.3	14	32%	24%	7%
The Mall (E/B)	0.297	49.7	21	8%	1%	19%
Western Road (E/B) [c]	1.042	361.9	10	40%	33%	7%
Western Road (W/B) [c]	1.042	219.5	17	25%	18%	14%

[a] For A40 Western Avenue (speed limit 40mph), % greater than 30mph

[b] Note that results include right turning traffic at Savoy Circus. Delays will be greater than the straight ahead movement due to relatively less green time at the traffic signals.

[c] Results influenced by presence of temporary traffic signals in the vicinity of the junctions with Albert Road / Leonard Road (gas main repairs).

Spatial aggregation of results

For reporting purposes, probe vehicle data was spatially aggregated to 100 metre sections by direction (200 metre sections on the A40 Western Avenue);

N.B. For the calculation of light vehicle emissions, ‘instantaneous’ (10Hz) data were utilised (speed, acceleration, local gradient, calculated engine load in kW etc.). Results were then spatially aggregated for reporting purposes.

Spatial disaggregation of case study areas

Example: Acton High Street

100 metre sections from west to east

Probe vehicle survey summary data

Acton High Street (eastbound)
Average speed (kph)

	Section								
Run	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**Combined**
1	14	25	11	28	11	27	27	27	**18**
2	19	7	20	21	11	23	22	16	**15**
3	17	9	18	14	11	16	19	33	**14**
4	25	8	29	14	30	26	30	33	**18**
5	7	15	24	17	12	20	30	32	**15**
6	12	10	17	6	20	11	24	31	**12**
7	13	13	20	27	23	16	8	22	**15**
8	25	10	33	16	29	16	11	26	**17**
9	13	23	19	18	14	26	21	24	**18**
10	7	26	31	10	14	19	31	36	**15**
11	32	32	27	26	30	31	34	34	**30**
12	6	16	24	24	10	21	34	35	**14**
13	5	16	20	31	9	18	21	19	**13**
14	31	12	17	16	14	12	25	27	**16**
15	12	21	9	11	14	24	26	28	**15**
16	17	20	9	26	9	22	24	33	**15**
17	26	9	26	27	10	16	28	33	**17**
18	19	8	30	34	10	25	23	23	**17**
19	16	10	23	18	10	29	32	39	**17**
20	12	10	22	21	11	21	29	34	**16**
21	17	12	12	33	33	24	22	20	**19**
22	4	10	11	17	10	20	30	31	**11**
23	34	30	10	17	13	20	27	34	**18**
24	7	9	20	34	32	25	29	32	**16**
25	9	20	16	27	9	21	30	35	**16**
26	6	27	9	31	17	29	30	35	**15**
27	33	31	22	5	10	26	28	34	**15**
28	6	24	13	30	10	28	19	22	**14**
29	5	12	21	12	13	18	31	34	**12**
30	11	17	26	33	17	22	29	36	**20**
Combined	**10**	**13**	**17**	**17**	**13**	**20**	**24**	**29**	**15**

Example: Acton High Street (eastbound).

Average speed (kph).

30 runs. Results summarised by 100 metre section.

Illustrates spatial variation (A, B, C…H), and variation by run.

Probe vehicle survey summary data

Acton High Street (eastbound)

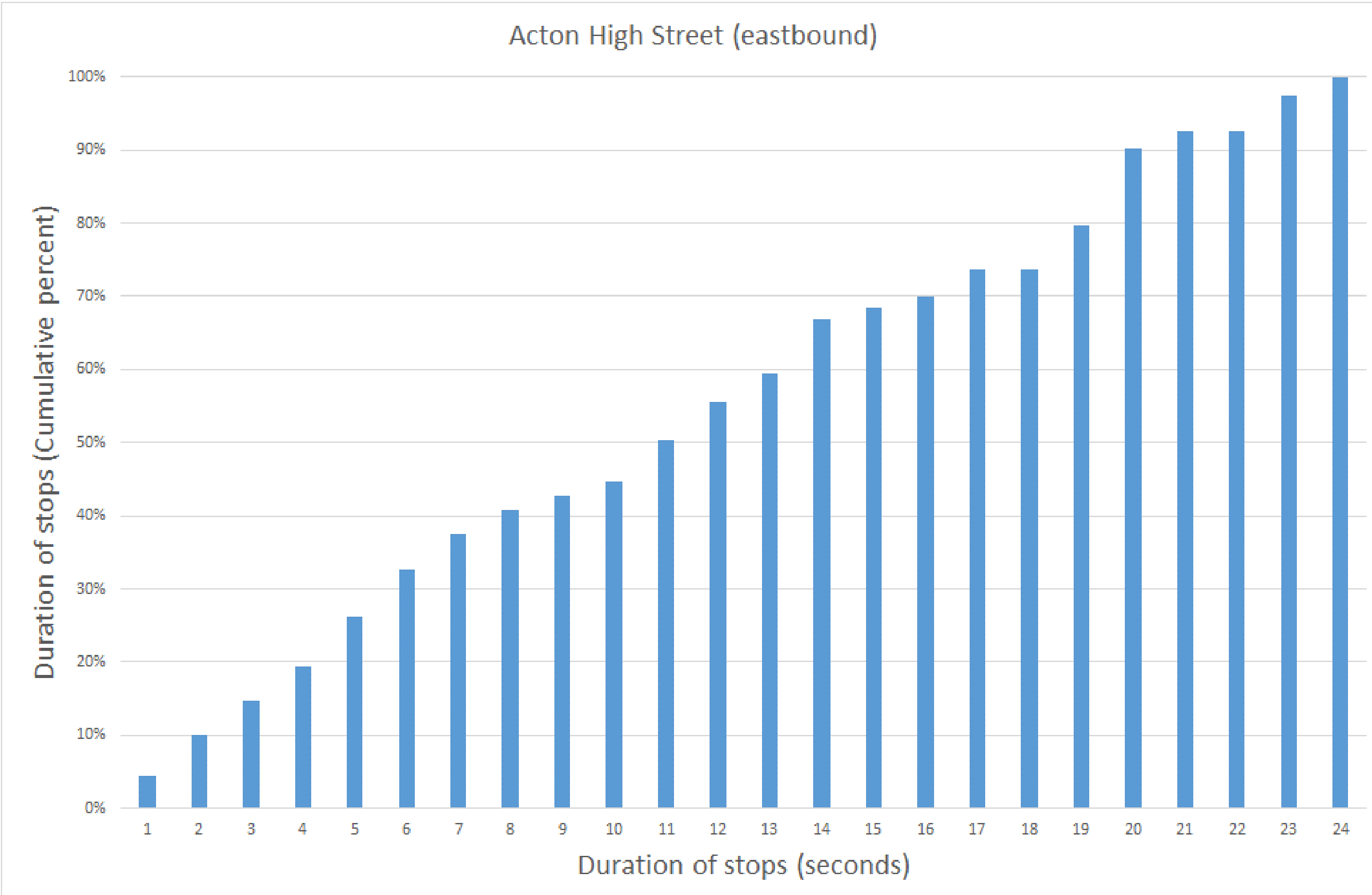
Percentage (%) time spent stationary

	Section								
Run	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**Combined**
1	15%	0%	48%	0%	34%	0%	0%	0%	**21%**
2	0%	31%	0%	0%	31%	0%	0%	0%	**15%**
3	0%	36%	0%	10%	31%	0%	0%	0%	**15%**
4	0%	52%	0%	9%	0%	0%	0%	0%	**19%**
5	35%	0%	0%	0%	13%	0%	0%	0%	**12%**
6	27%	27%	0%	28%	0%	16%	0%	0%	**19%**
7	17%	30%	0%	0%	0%	0%	36%	0%	**17%**
8	0%	53%	0%	7%	0%	0%	17%	0%	**18%**
9	9%	0%	0%	0%	0%	0%	0%	0%	**2%**
10	28%	0%	0%	16%	9%	0%	0%	0%	**13%**
11	0%	0%	0%	0%	0%	0%	0%	0%	**0%**
12	30%	8%	0%	0%	52%	0%	0%	0%	**22%**
13	42%	9%	0%	0%	50%	2%	0%	0%	**26%**
14	0%	42%	0%	17%	8%	19%	0%	0%	**15%**
15	37%	0%	29%	34%	1%	0%	0%	0%	**19%**
16	15%	0%	48%	0%	46%	0%	0%	0%	**25%**
17	0%	49%	0%	0%	14%	0%	0%	0%	**16%**
18	0%	51%	0%	0%	52%	0%	0%	0%	**27%**
19	0%	24%	0%	0%	28%	0%	0%	0%	**12%**
20	5%	45%	0%	0%	41%	0%	0%	0%	**19%**
21	0%	34%	26%	0%	0%	0%	0%	0%	**13%**
22	46%	0%	9%	0%	46%	0%	0%	0%	**24%**
23	0%	0%	46%	0%	16%	0%	0%	0%	**15%**
24	15%	55%	0%	0%	0%	0%	0%	0%	**19%**
25	12%	0%	0%	0%	31%	0%	0%	0%	**10%**
26	38%	0%	49%	0%	13%	0%	0%	0%	**26%**
27	0%	0%	0%	49%	37%	0%	0%	0%	**28%**
28	55%	0%	23%	0%	53%	0%	0%	0%	**31%**
29	47%	27%	0%	35%	20%	0%	0%	0%	**27%**
30	36%	0%	0%	0%	19%	0%	0%	0%	**12%**
Combined	**26%**	**27%**	**16%**	**14%**	**27%**	**2%**	**5%**	**0%**	**19%**

Example: Acton High Street (eastbound).

Percentage of journey time spent stationary.

Probe vehicle survey summary data



Example: Acton High Street (eastbound). Overall 923.8 seconds stationary over all runs, 413.3 seconds for ≤10 secs (45%), 510.5 seconds for >10 secs (55%).

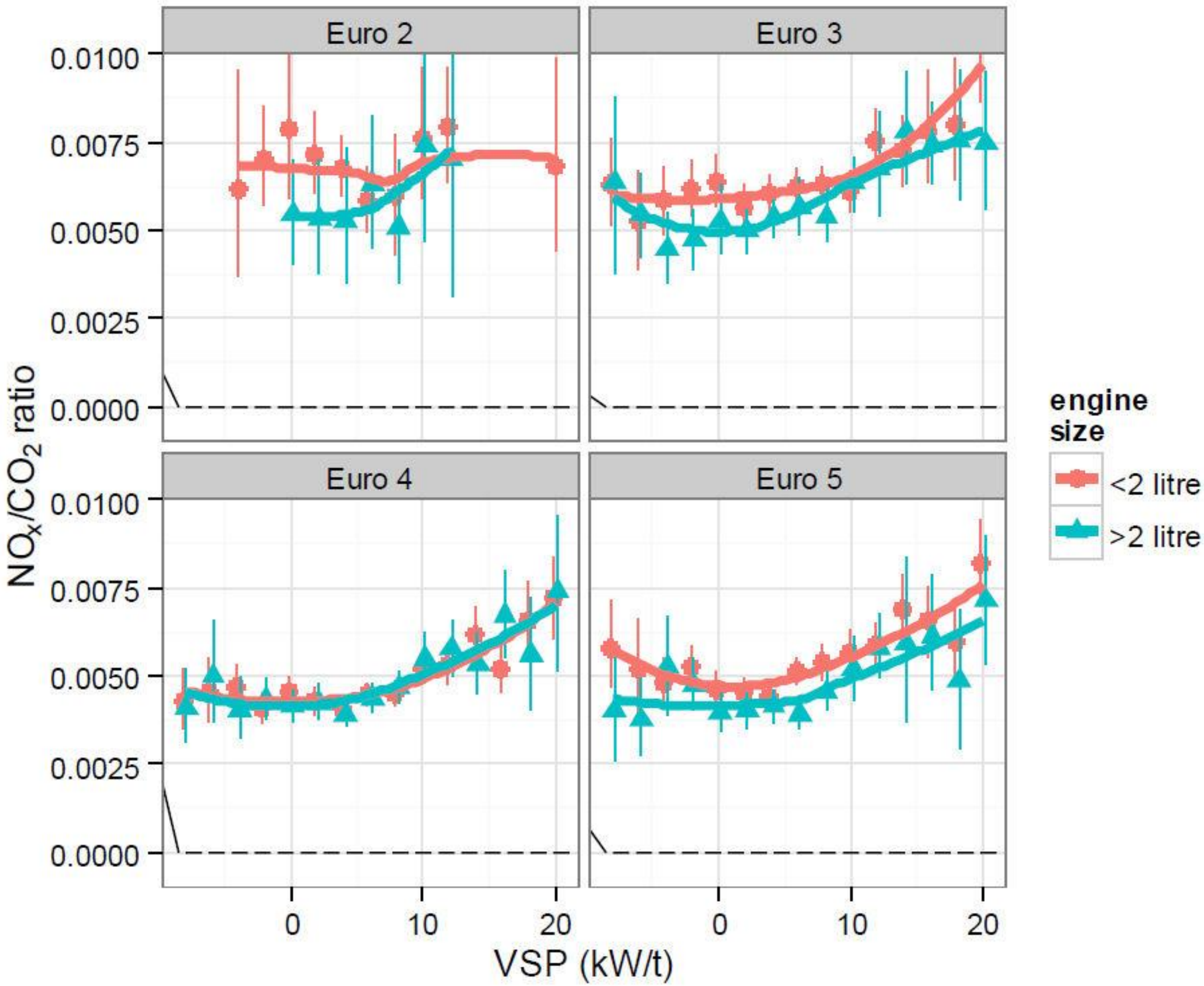
Light vehicle emission rates at 2012

Primary NO_2 and NO emission data collected in 2012 were processed to conform to the following 28 light vehicle type categories:

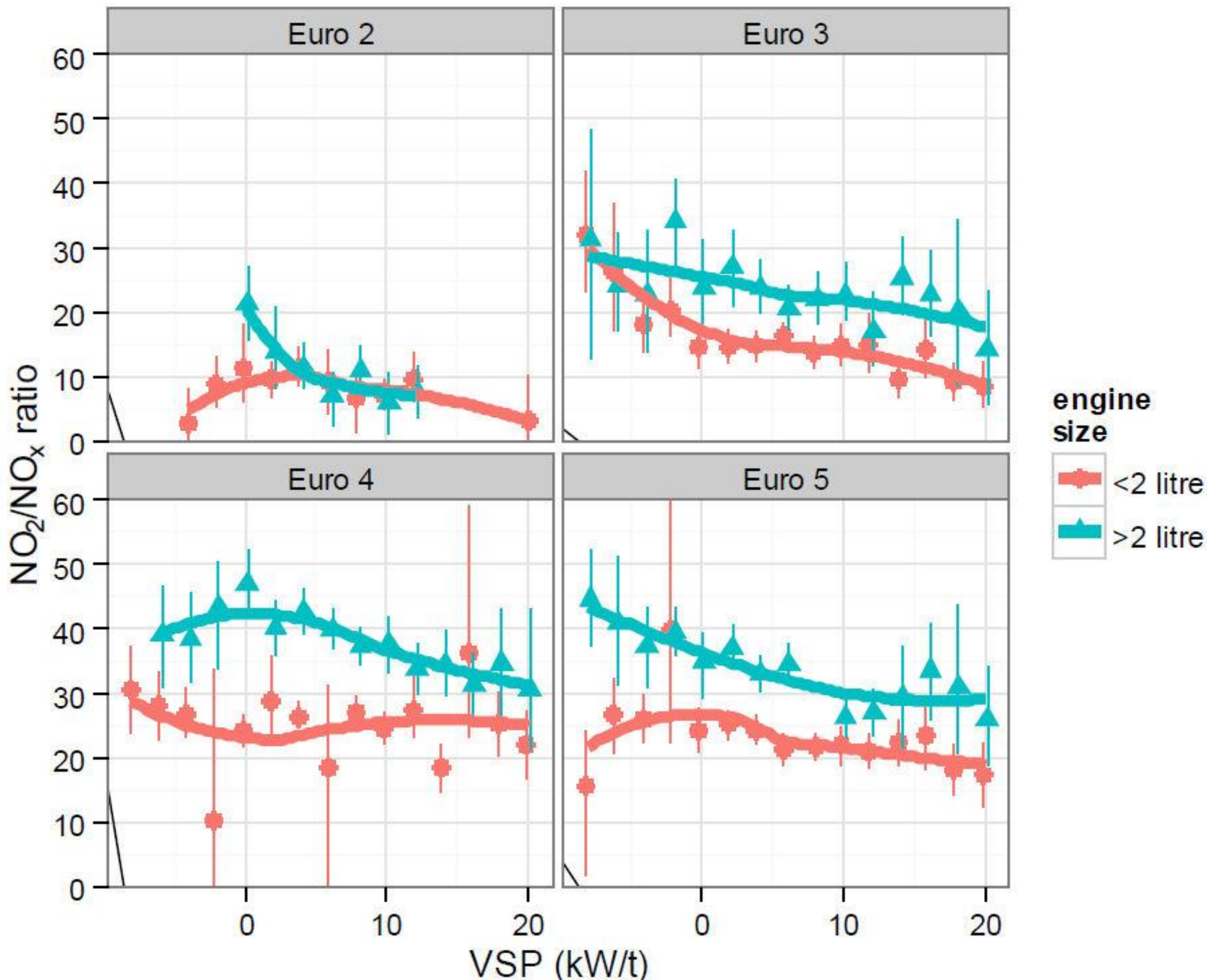
- Passenger cars (M1) by fuel type, ‘Euro’ standard, and COPERT engine capacity class (**15 categories**);
- Diesel vans (N1) by ‘Euro’ standard (**3 categories**);
- Diesel taxis (black cabs) by model and ‘Euro’ standard (**10 categories**).

Emission observations with valid speed and acceleration measurements were utilised to define the dynamic relationship between emission rates, and the corresponding levels of engine load.

Diesel car – NO_x vs VSP



Diesel car – NO_2 vs VSP



Calculation of engine load power (W)

Engine load power (W) =

$(C_f \times m \times g) \times v$	Rolling resistance power (W)
$+ (0.5 \times \rho \times C_d \times A \times v^2) \times v$	Aerodynamic drag power (W)
$+ ((m \times g \times \sin(\alpha)) \times v$	Gradient power (W)
$+ (a \times m \times v \times k_m)$	Acceleration power (W)

where:

Quantity	**Description**	**Units**
W	Power	Watts
m	Vehicle mass	kg
v	Vehicle speed	m/s
a	Vehicle acceleration	m/s^2
α	Highway gradient	Degrees °
C_d	Drag coefficient	Constant
A	Vehicle frontal area	m^2
ρ	Air density	kg/m^3
C_f	Coefficient of rolling resistance	Constant
k_m	Rotational inertia coefficient	Constant
g	Gravity	m/s^2

Calculating case study area light vehicle emissions at 2012

- The basic approach entails integrating the 2012 remote sensing emissions data with the probe vehicle survey results collected in the case study areas.
- **Essentially, emissions results are generated for each light vehicle class in each case study area, as if each of the different light vehicle classes were being driven through the case study routes in a manner (speed, acceleration, stops, delays) characterised by the data collected in the probe vehicle surveys.**
- 28 different light vehicle classes

Calculating case study area light vehicle emissions at 2012

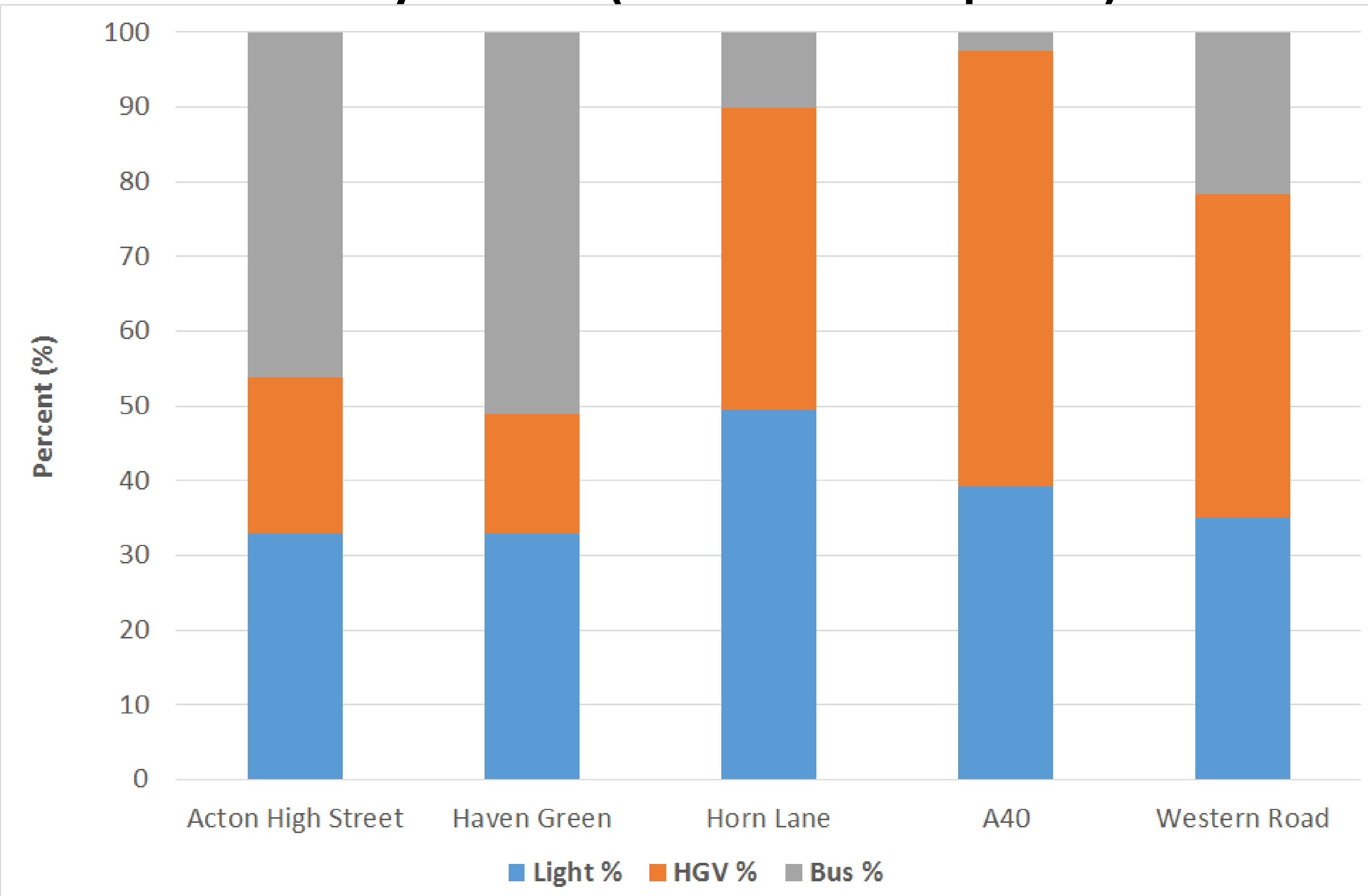
Simplifying a little:

1. Calculate kW values from probe vehicle data at 10Hz for each of the 28 vehicle categories (e.g. Acton High Street eastbound = 1,382,528 calculated values);
2. Assign NO and NO_2 emission rate values (g/kg) to each data value;
3. Calculate NO and NO_2 (g/kg) summary statistics (mean, percentiles etc.) for each case study area, by direction, geographic section, and vehicle category;
4. Calculate absolute NO and NO_2 emissions in grams (emissions rate g/kg x journey time secs x fuel consumption rate kg/sec x traffic flow by vehicle category and time period).

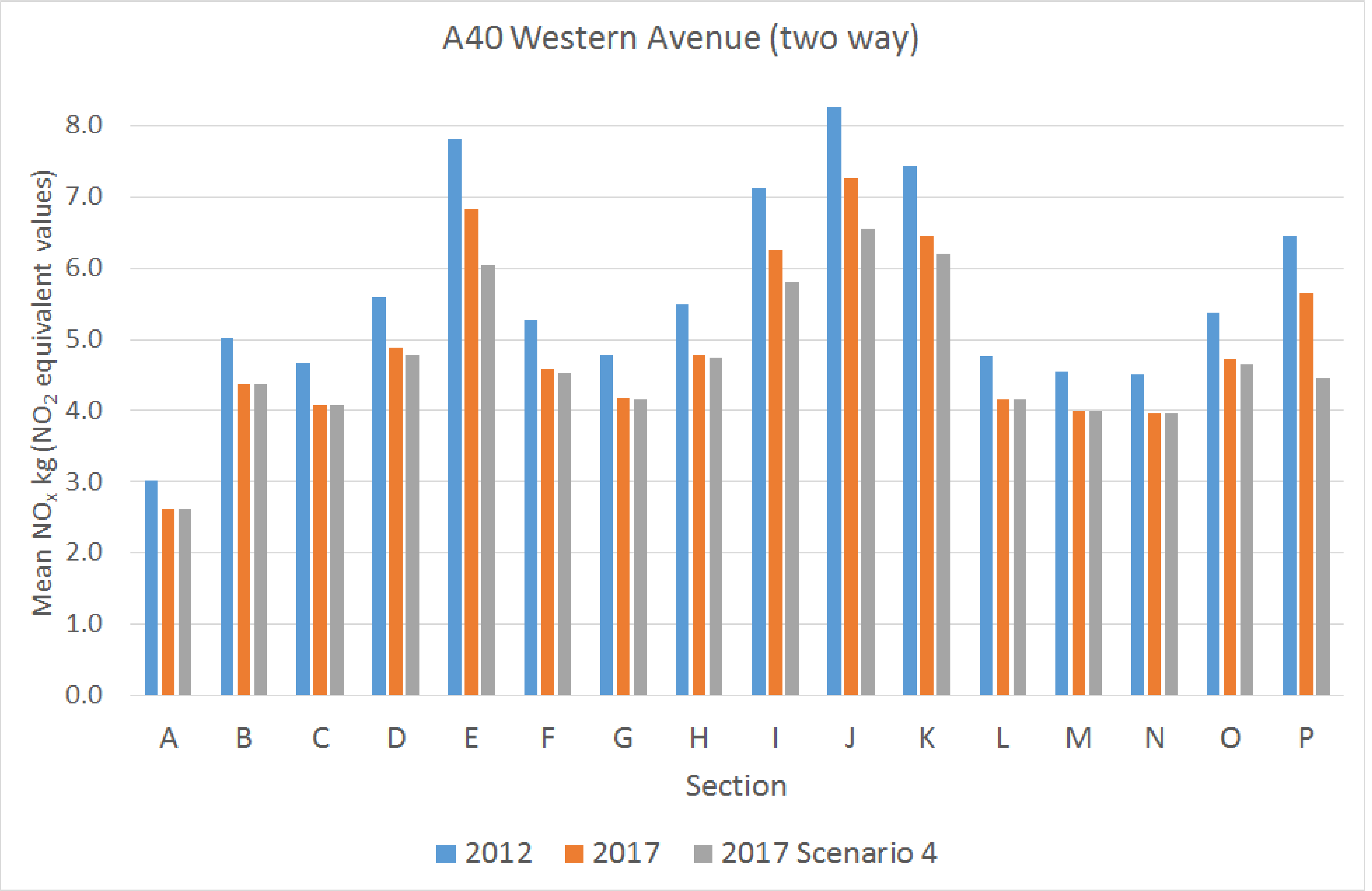
Heavy vehicle emission rates at 2012

- Simplified approach adopted (see report for details).
- Mean HGV emission rates derived from 2012 RSD surveys (N2 Euro II, III, IV, & V; N3 Euro II, IV, V). Be careful of small sample size and potential sampling bias.
- Simple distance based approach adopted, using published DfT fuel consumption data, and traffic volumes by class.
- Similar simplifications adopted for buses, using fuel consumption data supplied by TfL. Variation in bus type by case study location / route (10 types).

NO_x source apportionment 2012 by case study area (road transport)



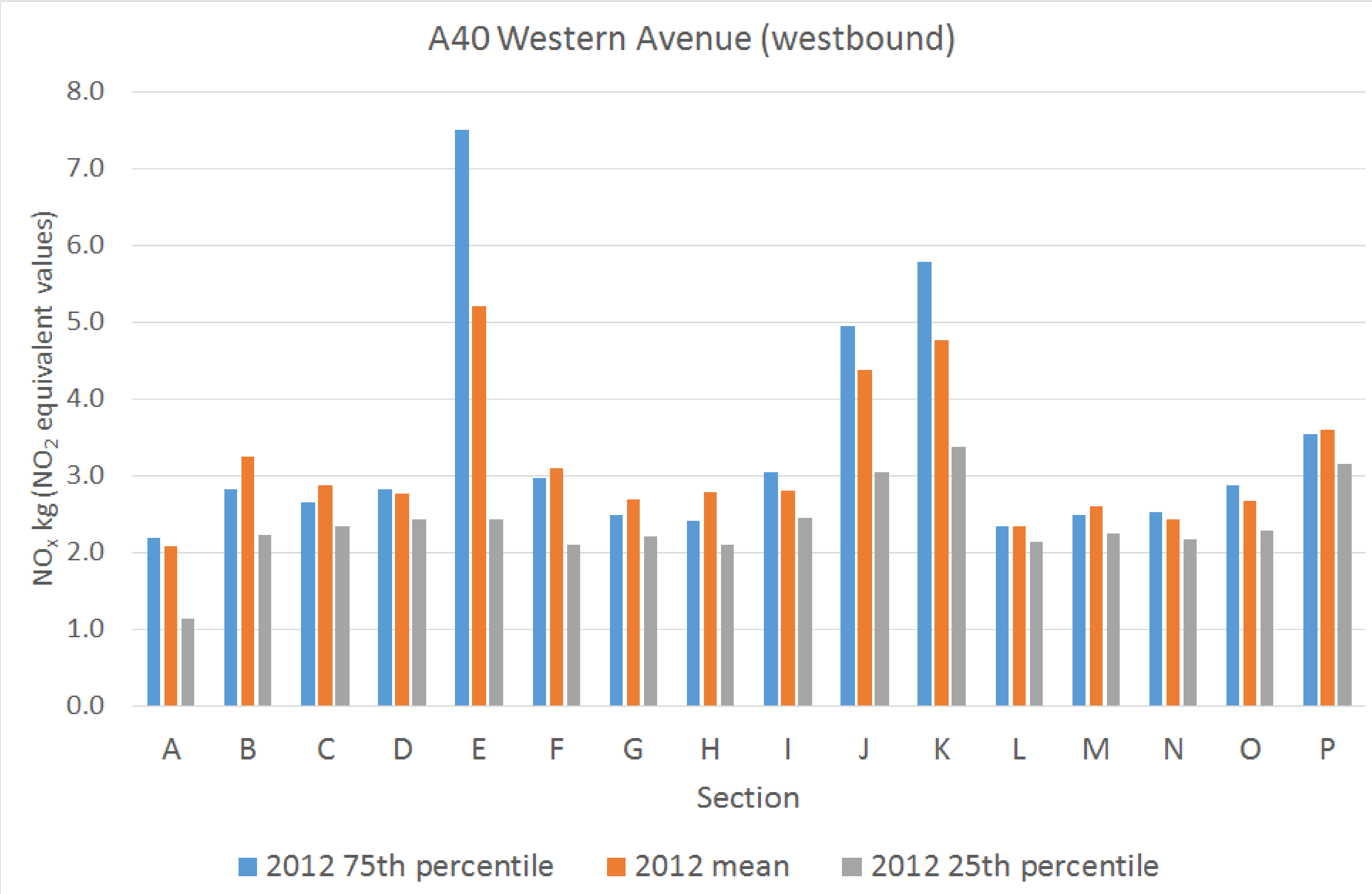
Intra case study area spatial variation



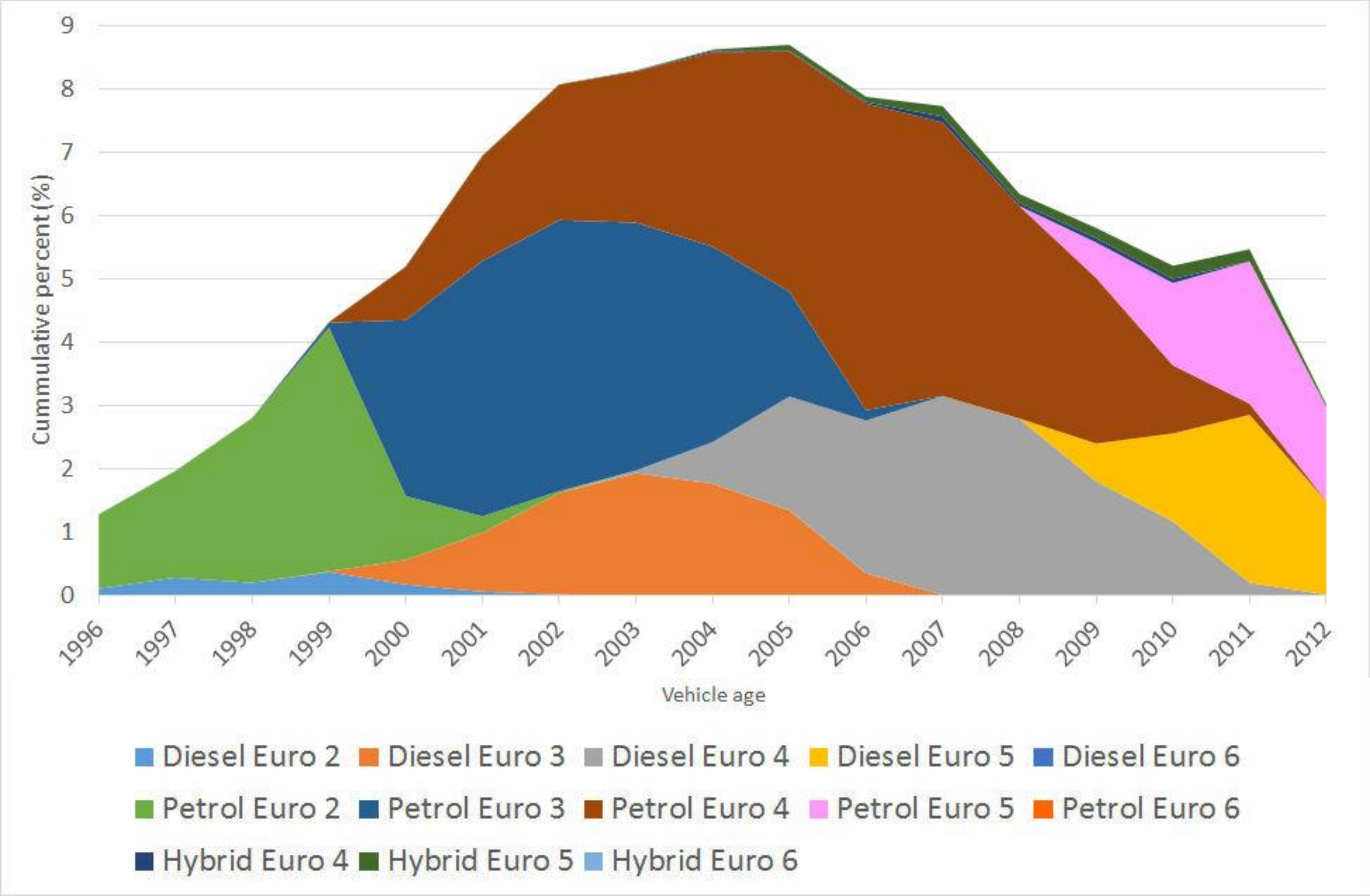
Intra case study area spatial variation

A40 Western Avenue

Intra case study area variability by run



Passenger car fleet mix at 2012

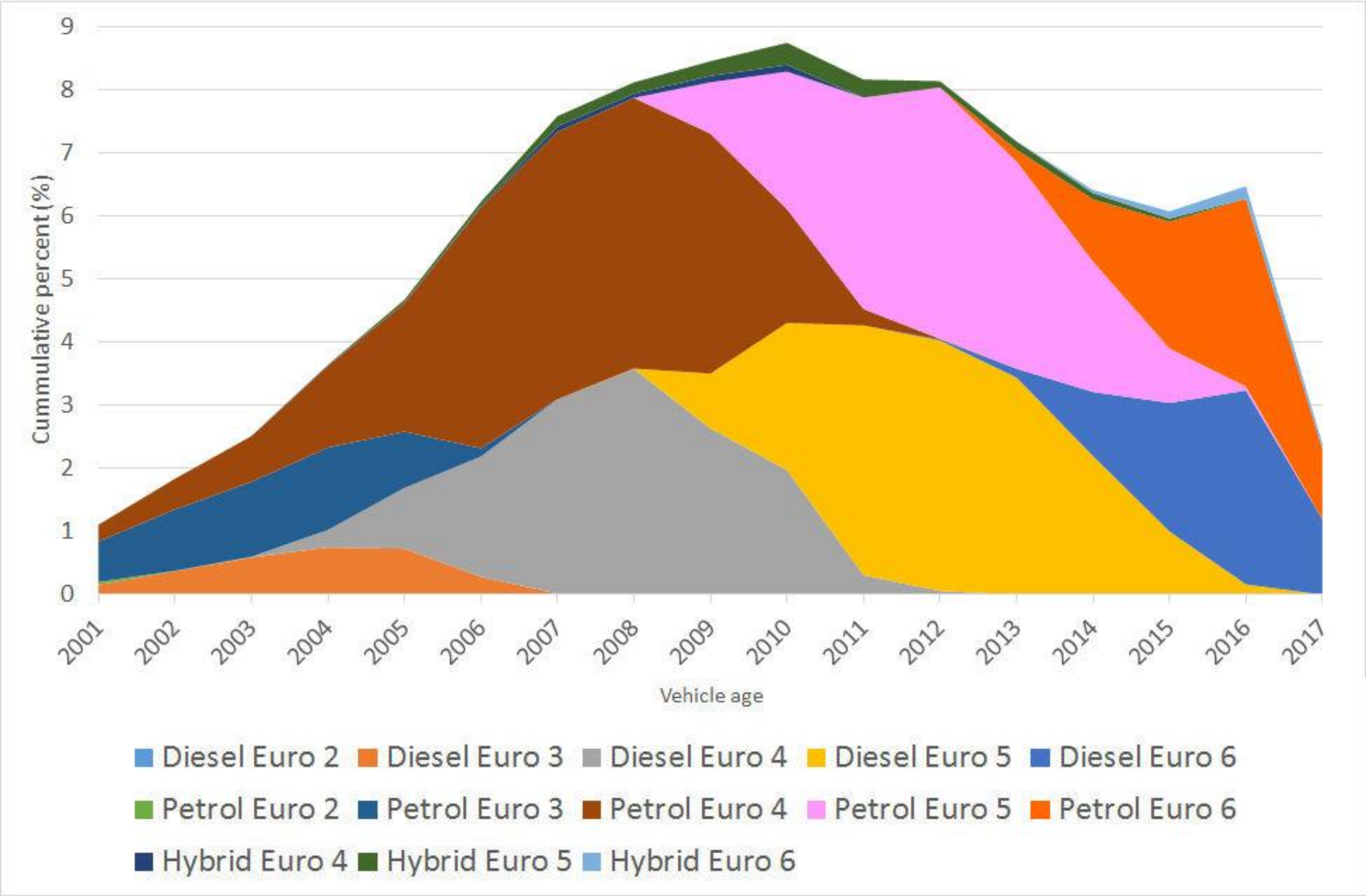


Future year fleet mix assumptions

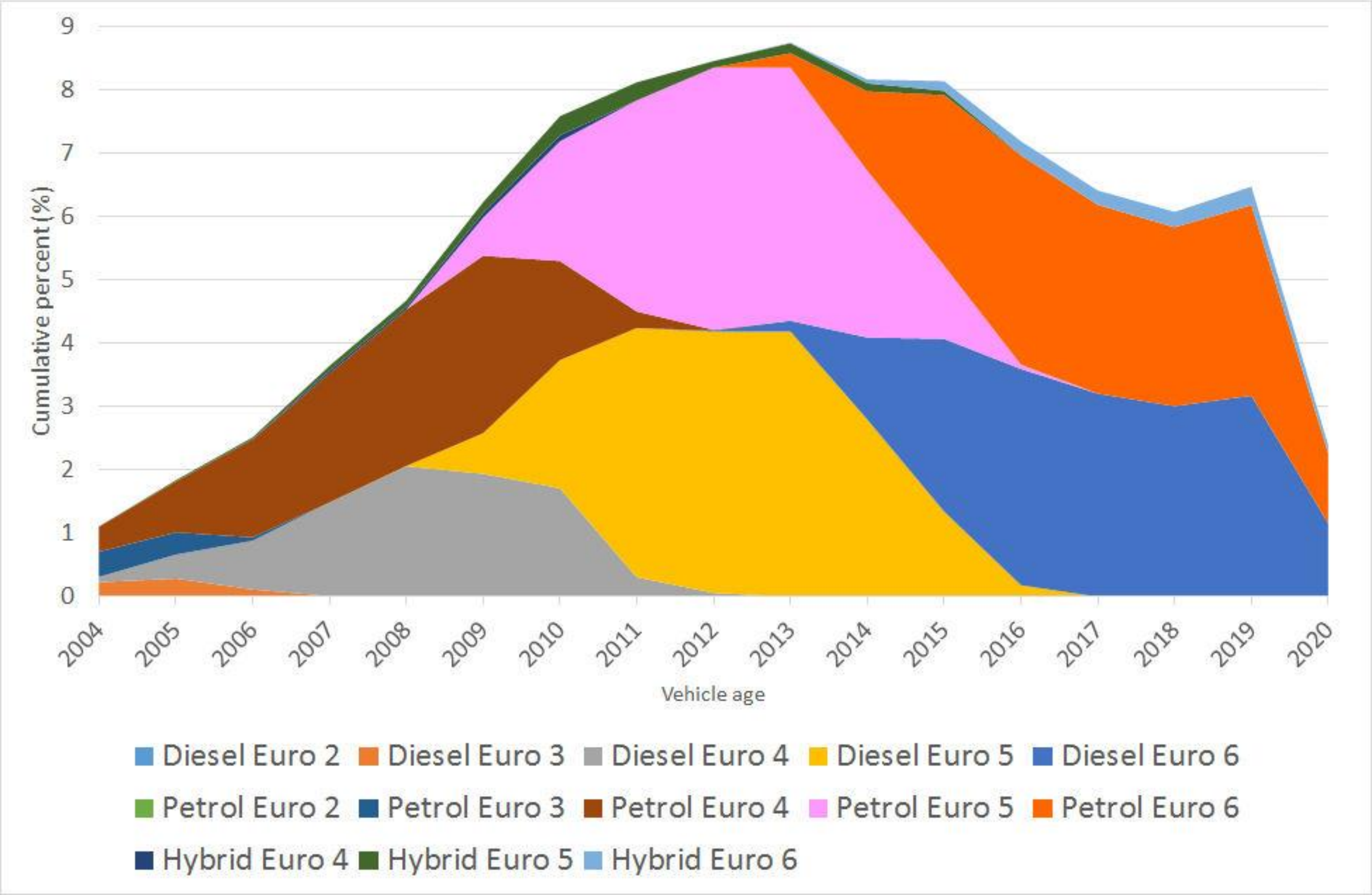
Need to be defined

- Age profile
- Market share by fuel type
- Market share by engine capacity
- Market share by Euro emissions standard

Passenger car fleet mix at 2017



Passenger car fleet mix at 2020



Example tabular abstract at 2017

Table 35: Mean NO (grams) in 2017: Light vehicles, average weekday (12 hour period)

		AHEB	AHWB	HGEB	HGLP	HGWB	HLNB	HLSB	WAEB	WAWB	WREB	WRWB	Total
Car Diesel													
< 2.0 l	Euro 0	0	0	0	0	0	0	0	1	1	0	0	**4**
	Euro 1	0	1	0	1	0	1	0	4	4	1	1	**13**
	Euro 2	3	6	2	8	3	12	5	43	49	11	8	**149**
	Euro 3	47	81	23	112	34	159	66	605	720	154	107	**2109**
	Euro 4	161	282	80	389	118	558	232	2112	2498	538	371	**7340**
	Euro 5	202	344	102	483	145	683	295	3069	3657	654	464	**10097**
	Euro 6	39	66	20	93	28	132	57	593	707	127	90	**1953**
> 2.0 l	Euro 0	0	0	0	0	0	0	0	1	1	0	0	**5**
	Euro 1	0	1	0	1	0	1	0	4	4	1	1	**13**
	Euro 2	2	3	1	4	1	6	3	24	27	6	4	**82**
	Euro 3	23	41	11	55	17	80	32	281	336	77	52	**1004**
	Euro 4	69	118	35	166	50	236	101	903	1114	225	160	**3177**
	Euro 5	54	93	27	130	39	185	78	721	883	178	124	**2511**
	Euro 6	8	14	4	20	6	29	12	111	136	27	19	**387**
	Sub total												**28843**
Car Petrol													
< 1.4 l	Euro 0	1	2	1	2	1	4	1	13	15	3	2	**45**
	Euro 1	2	3	1	4	1	6	2	21	24	6	4	**73**
	Euro 2	6	9	3	13	4	19	8	76	92	18	13	**261**
	Euro 3	10	17	5	23	7	33	14	131	155	32	23	**449**
	Euro 4	30	53	16	74	22	106	45	416	531	100	71	**1466**
	Euro 5	17	25	9	39	11	53	26	235	277	49	38	**780**
	Euro 6	8	12	4	19	5	26	13	115	135	24	19	**381**
1.4 - 2.0 l	Euro 0	2	4	1	5	2	8	3	27	31	8	5	**96**
	Euro 1	3	5	1	7	2	10	4	37	42	10	7	**129**
	Euro 2	17	29	9	40	12	57	24	211	249	55	39	**742**
	Euro 3	24	42	12	56	17	80	32	287	344	79	54	**1027**
	Euro 4	60	104	30	145	44	208	86	766	920	199	140	**2702**
	Euro 5	9	14	5	22	6	29	15	129	164	27	21	**440**
	Euro 6	3	5	2	7	2	10	5	45	57	9	7	**152**
> 2.0 l	Euro 0	1	1	0	2	1	3	1	10	11	3	2	**34**

Emissions ‘hot spot’ due to queuing

Example scenarios

NO_x Index	Acton High Street	Haven Green	Horn Lane	A40	Western Road
2012 (Index=100)	100	100	100	100	100
2017 Business as usual	92.2	90.5	91.4	90.8	89.1
2017 Scrappage 10%	91.6	89.9	90.4	90.0	88.4
2017 Scrappage 20%	91.0	89.2	89.5	89.2	87.7
2017 Reduce diesel	92.1	90.4	91.3	90.7	89.0
2017 Switch off engines	91.3	89.2	87.5	90.1	87.1
2017 ULEZ	85.8	84.1	81.8	83.1	82.2

Acton High Street	Location	
NO_2 µg/m^3 annual mean	88 High Street	182 High Street
2012 Observed	**54.7**	**48.9**
2017 Business as usual	**47.9**	**43.2**
2020 Business as usual	**41.1**	37.4
2017 Scrappage 10%	**47.4**	**42.7**
2017 Scrappage 20%	**46.8**	**42.3**
2017 Reduce diesel	**47.9**	**43.1**
2017 Switch off engines	**47.1**	**42.5**
2017 ULEZ	**42.4**	38.5

Example scenarios

Horn Lane	Location	
NO_2 µg/m^3 annual mean	156 Horn Lane	Horn Lane AQMS
2012 Observed	**40.7**	**54.7**
2017 Business as usual	36.0	**47.2**
2020 Business as usual	31.4	39.9
2017 Scrappage 10%	35.5	**46.4**
2017 Scrappage 20%	35.0	**45.6**
2017 Reduce diesel	35.9	**47.1**
2017 Switch off engines	33.9	**43.8**
2017 ULEZ	30.8	38.9

A40 Western Avenue	Location			
NO_2 µg/m^3 annual mean	Wendover Court	Western Ave AQMS	98 Western Avenue	6 Western Avenue
2012 Observed	**56.0**	**75.1**	**51.8**	**70.8**
2017 Business as usual	**47.7**	**62.8**	**44.4**	**59.4**
2020 Business as usual	39.3	**50.1**	36.9	**47.7**
2017 Scrappage 10%	**47.0**	**61.7**	**43.8**	**58.4**
2017 Scrappage 20%	**46.3**	**60.7**	**43.2**	**57.4**
2017 Reduce diesel	**47.6**	**62.6**	**44.3**	**59.2**
2017 Switch off engines	**47.1**	**61.8**	**43.9**	**58.5**
2017 ULEZ	**40.8**	**52.5**	38.2	**49.8**

Volkswagen revelations

VW scandal: 1.2m UK vehicles affected

1 hour ago | Business

Volkswagen has announced that nearly 1.2 million of its vehicles sold in the UK are fitted with the software behind the emissions scandal.

VW crisis

Fuel security…

Diesel pumps could run dry, says RAC Foundation

By Richard Westcott
BBC Transport Correspondent

7 hours ago | Business | 685

Issues for consideration (1)

- Some aspects of local air quality management would benefit from closer attention, e,g, the management and monitoring of local air quality ‘hot spots’. Quantify the impact on emissions of idling at traffic signals; quantify the impact on air quality and receptors; assess the penetration and potential efficacy of ‘stop/start’ systems; explore the potential for ‘infrastructure to driver’, or ‘infrastructure to vehicle’ communication;
- Important not to underestimate the challenge of dealing with the ‘legacy’ effect of vehicles already on the network (which will remain for many years unless interventions are made). ‘Cleaner’ new vehicles will take many years to penetrate the fleet;
- The UK would benefit from a systematic and effective system for monitoring ‘real world’ vehicle emissions performance and time trends (as new technologies enter the fleet, and as vehicles age), and the impact these emissions have on local air quality and health;

Issues for consideration (2)

- Review of UK ‘MoT’ test procedures?? Include NOx??
- Champion a more ‘joined up’ approach between Defra, DfT, Health, and Treasury;
- It would be highly desirable to explore the potential for integrating emissions data sources (remote sensing, PEMS, laboratory vehicle measurements). Capitalise on strengths, and mitigate weaknesses (e.g. variability in driver behaviour, instantaneous fuel consumption, idling characteristics etc.);
- The medium and long term consequences of the recent Volkswagen revelations, in terms of market responses, fiscal measures, and impact on the EU and UK regulatory framework, are yet to be determined (uncertainty);
- Try to avoid ‘unintended consequences’ of interventions (again). Role for a ‘devils advocate’ to challenge received wisdom.

Acknowledgements

- Defra and London Borough of Ealing for funding
- Dr John Freeman, Rizwan Yunus, and Russell Roberts (London Borough of Ealing)
- Finn Coyle (TfL) for bus information
- David Pryke (DfT)
- Martin Taylor (SMMT)

- Aerial photographs © Google Earth Pro.

Thank you

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