North Staffordshire Local Air Quality Plan - Air Quality Modelling Methodology Report (AQ2)

Report for Stoke-on-Trent City Council and Newcastle-under-Lyme Borough Council

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1 Introduction and outline modelling scope

North Staffordshire, like many areas across the UK, continues to experience areas of poor air quality. Stoke-on-Trent City Council and Newcastle-under-Lyme Borough Council (the Councils), along with 32 other Local Authorities, received a Ministerial Direction on the 23rd March 2018 to undertake a feasibility study into nitrogen dioxide (NO_2) compliance. Following this feasibility study, the Councils received another Ministerial Direction to undertake a NO_2 Local Plan Development.

1.1 Context

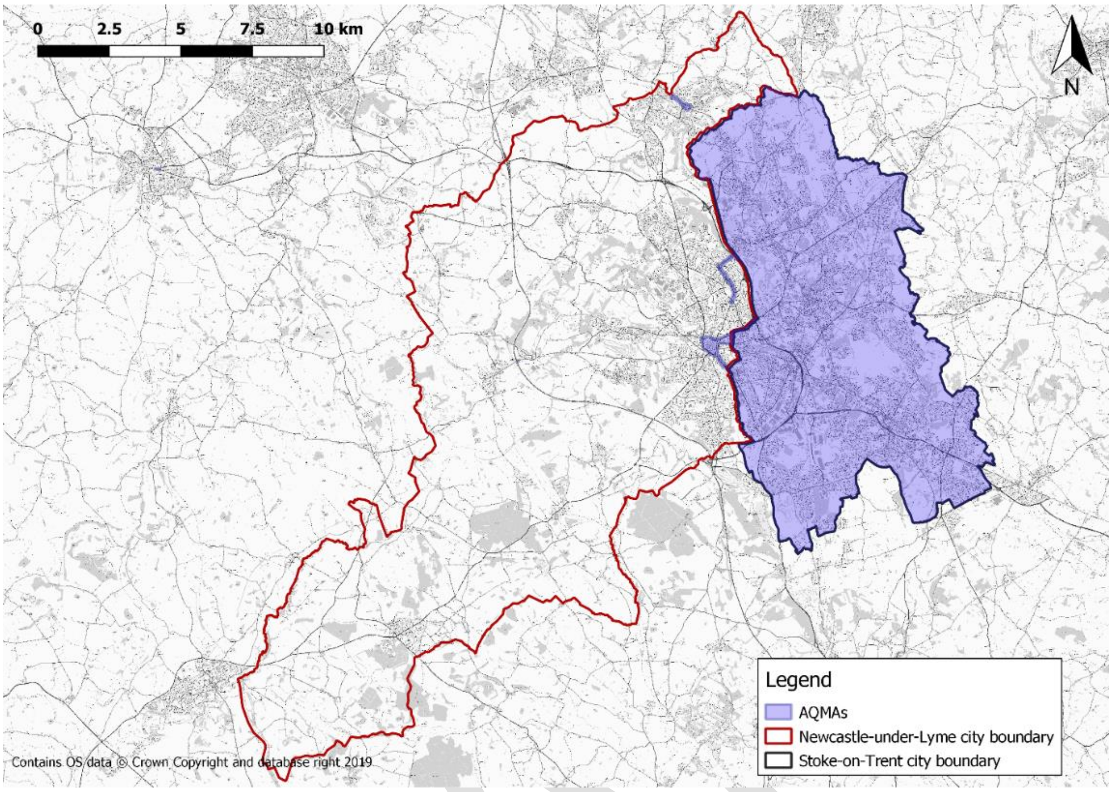
Stoke-on-Trent and Newcastle-under-Lyme have locations where NO_2 concentrations are in excess of national and European air quality standards. Newcastle-under-Lyme Borough Council (NULC) has declared 4 Air Quality Management Areas (AQMAs) for annual mean NO_2 concentrations across the borough to date, all of which are in the proposed model domain. Stoke-on-Trent City Council has declared a single AQMA encompassing the whole city for annual mean and hourly mean NO_2 concentrations. These AQMAs are detailed in Table 1-1 below. A map showing the locations of these AQMAs is presented in Figure 1-1. The associated Local Air Quality Management (LAQM) assessment work has concluded that these exceedances are mainly attributable to emissions from road traffic.

Table 1-1: AQMAs in the model domain

Local Authority	AQMA	Description	Date Declared	Pollutants
Newcastle-under-Lyme	AQMA 1 - Kidsgrove	Declared due to exceedance of the NO_2 annual mean objective along Liverpool Road A50, Kidsgrove	15/01/2015	NO_2 (annual)
	AQMA 2 - Town	Covers Newcastle under Lyme Town Centre including the ring road, A53, King Street, George Street and London Road to the boundary with the City of Stoke on Trent AQMA	15/01/2015	NO_2 (annual)
	AQMA 3 - Maybank, Wolstanton, Porthill	Covers the principal routes between Maybank, Wolstanton and Porthill.	15/01/2015	NO_2 (annual)
	AQMA 4 - Little Madeley	Declared around two properties at Little Madeley.	15/01/2015	NO_2 (annual)
Stoke-on-Trent	Stoke AQMA	An area encompassing the whole city of Stoke-on-Trent.	04/04/2006 Amended 09/05/2011	NO_2 (hourly and annual)

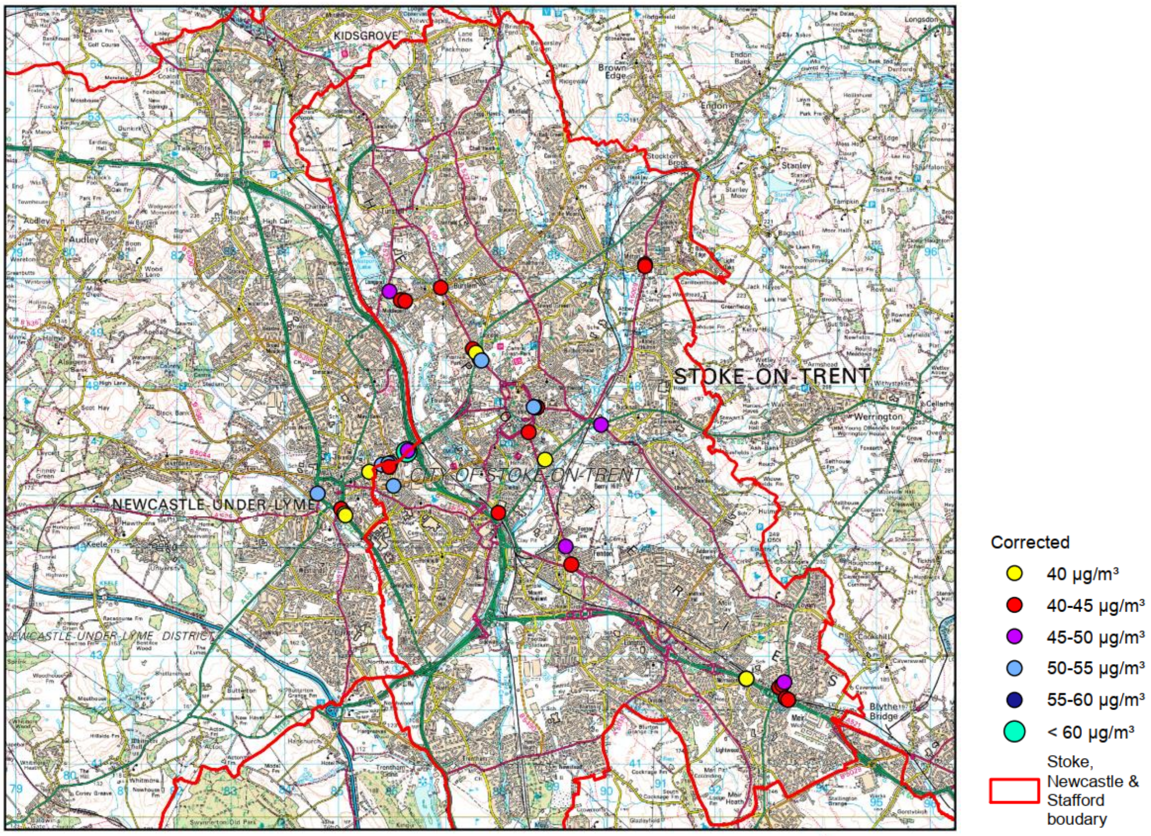
Defra compliance modelling has identified two road links which are predicted to exceed the UK Air Quality Objective for annual mean NO_2 concentrations in 2020; these links comprise the length of the A53 (Etruria Road) from Festival Park roundabout to the A500 roundabout. An NO_2 feasibility study carried out in 2018 extended the area of predicted non-compliance to include census IDs 28732 and 6545. The locations of monitored exceedances of the Air Quality Objective for annual mean NO_2 concentrations are presented in Figure 1-2.

Figure 1-1: SOTC and NULC Air Quality Management Areas (AQMAs)



Contains OS data © Crown Copyright and database right 2019

Figure 1-2: Locations of monitored NO_2 exceedances in 2018 (provided by Stoke-on-Trent Council)



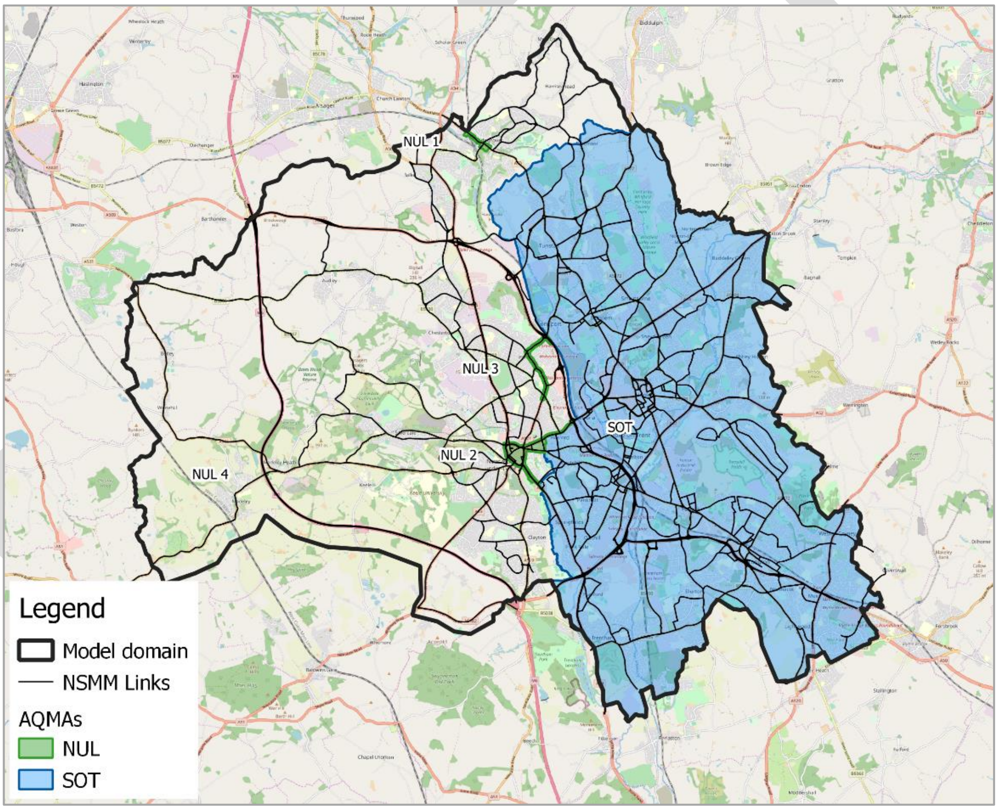
1.2 Model domain

To assess the transport and air quality impacts of the scheme, a model domain is required that covers the potential scheme options, relevant AQMAs and possible diversion routes. The core air quality model domain covers the Stoke-on-Trent and Newcastle-on-Lyme boundaries, based upon the district boundary from Ordnance Survey mapping products[1], and is derived from the extent of the North Staffordshire Multi-Modal traffic model (NSMM) on which the air quality modelling is based. The model domain used is shown in Figure 1-3 and has been chosen to cover the following:

- All of the AQMAs in Stoke-on-Trent and Newcastle-under-Lyme;
- The main areas of concern identified in the national modelling assessment at the A53 road link and the A500;
- Areas of concern identified from SOTC and NULC measurement data.
- All potential displacement routes from measures targeting areas of concern.

Concentrations were calculated across a grid covering this area at 3m resolution.

Figure 1-3: CAZ study domain and relationship to transport model links



A map showing the model domain relative to roads included in the national Pollution Climate Mapping (PCM) model is presented in Figure 1-4. Note that all road links shown in Figure 1-3 are included in the model domain, including road links with no exceedances in PCM, and roads which are not present in

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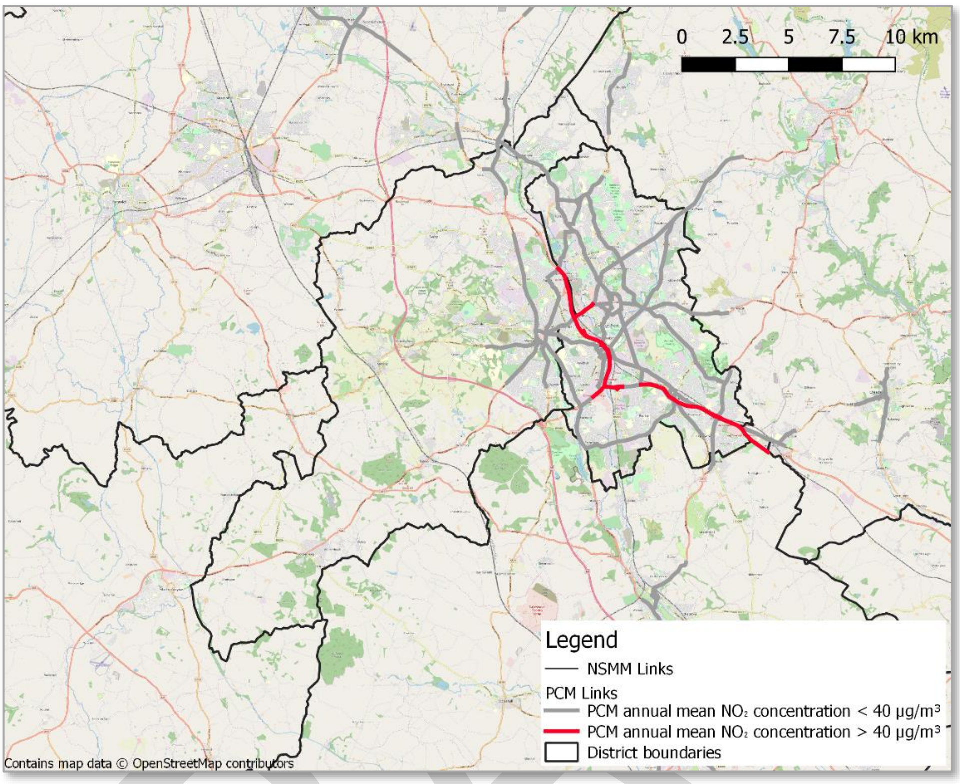
[1] https://www.ordnancesurvey.co.uk/opendatadownload/products.html

PCM. The model domain is sufficiently wide to include all displacement routes, allowing the impacts of traffic displacement due to implementation measures to be evaluated fully.

Figure 1-4: PCM model road links with modelled annual mean NO_2 concentrations for 2015, μg.m^{-3}



1.3 Model years

There are two key years used in the modelling work, as set out in Table 1-2 below, plus an additional future reference year. The baseline modelling year is 2018 as this allows use of the latest air quality and transport data.

The future baseline was modelled for the assumed compliance year with the introduction of measures, 2022. Any interim years were generated through interpolation rather than direct model tests.

Table 1-2: Key model years

Year	Description
2018	**Base year** – using latest available data on air quality and traffic.
2022	**Compliance year** – earliest date when compliance could be achieved with measures.

1.4 Background modelling

The primary cause of the localised air pollution problems in the model domain is road traffic emissions. As such the focus of the modelling study is on these emissions.

Background pollutant concentrations for the UK are published by Defra[2]. The background mapping data provides estimates of annual mean background concentrations of key pollutants at a resolution of 1 x 1 km for the UK projected from a base year of 2017. These background maps were used to provide spatially-varying background concentrations which included all other sources for all model years. Impacts from all road sources were removed from the background data.

2 Model description

2.1 Model selection

The RapidAir© dispersion modelling system was used for the study. This is Ricardo Energy & Environment's proprietary modelling system developed for urban air pollution assessment. Information regarding compliance with the JAQU technical requirements is set out in AQ1 the Air Quality Modelling Tracking Table with further description of the model also provided here.

The model is based on convolution of an emissions grid with dispersion kernels derived from the USEPA AERMOD[3] model. The physical parameterisation (release height, initial plume depth and area source configuration) closely follows guidance provided by the USEPA in their statutory road transport dispersion modelling guidance[4]. AERMOD provides the algorithms which govern the dispersion of the emissions and is an accepted international model for road traffic studies (it is one of only two mandated models in the US and is widely used overseas for this application). The combination of an internationally recognised model code and careful parameterisation matching international best practice makes RapidAir demonstrably fit for purpose for this study.

The model produces high resolution concentration fields at the city scale (1 to 3m scale) so is ideal for spatially detailed compliance modelling. A validation study has been conducted in London using the same datasets as the 2011 Defra inter-comparison study[5]. Using the LAEI 2008 data and the measurements for the same time period the model performance is consistent (and across some metrics performs better) than other modelling solutions currently in use in the UK. A RapidAIR model validation paper has also recently been published with our partners at Strathclyde University in the well-known Environmental Modelling and Software journal[6].

2.2 Core aspects of the modelling

2.2.1 Chemistry, meteorology and topology

NOx to NO_2 chemistry was modelled using the Defra NOx/NO_2 calculator (v7.1). Modelled annual mean road NOx concentrations were combined with background NOx and a receptor-specific f-NO_2 fraction to calculate NO_2 annual mean concentrations. The receptor-specific f-NO_2 fraction was calculated by dividing the modelled road primary NO_2 contribution by the modelled road NOx contribution at each receptor. Further information is provided in Section 3.

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[2] https://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html
[3] https://www3.epa.gov/ttn/scram/dispersion_prefrec.htm#aermod
[4] https://www.epa.gov/state-and-local-transportation/project-level-conformity-and-hot-spot-analyses
[5] https://uk-air.defra.gov.uk/research/air-quality-modelling?view=intercomparison

[6] Masey, Hamilton, Beverland (2018) Development and evaluation of the RapidAir® dispersion model, including the use of geospatial surrogates to represent street canyon effects

2.2.2 Meteorology

Modelling was conducted using the 2018 annual surface meteorological dataset measured at Leek Thorncliffe. The dataset was processed in house using our own meteorological data gathering and processing system. We used freely available overseas meteorological databases which hold the same observations as supplied by UK meteorological data vendors. Our RapidAir model also takes account of upper air data which is used to determine the strength of turbulent mixing in the lower atmosphere; this was obtained from the closest radiosonde site and processed with the surface data in the USEPA AERMET model. We have utilised data filling where necessary following USEPA guidance which sets out the preferred hierarchy of routines to account for gaps (persistence, interpolation, substitution). AERMET processing was conducted following the USEPA guidance. To account for differences between the meteorological site and the dispersion site, surface parameters at the meteorological site were included as recommended in the guidance and the urban option specified for the dispersion site.

Following sensitivity testing and model verification, a uniform surface roughness value of 1.0 m was used to represent a typical city/urban environment. A surface roughness of 0.3 m was used to represent the meteorological measurement site.

2.2.3 Road geometry

Road geometry information was derived from the Ordnance Survey Mastermap Integrated Transport Network Roads dataset; this is the most accurate available road geometry dataset at the time of writing, containing road centreline locations for all road categories.

2.2.4 Canyon modelling

The presence of buildings either side of a road can introduce ‘street canyon’ effects which result in pollutants becoming trapped, leading to increased pollutant concentrations. The densely packed buildings and narrow roads of central Hanley and Stoke produce a large number of street canyons, which contribute significantly to air quality issues in the city centre.

The RapidAir model includes the AEOLIUS model which was developed by the UK Met Office in the 1990s. The AEOLIUS model was originally developed as a nomogram procedure[7]. The scientific basis for the model is presented in a series of papers by the Met Office[8,9,10,11,12]. The model formulation shares a high level of commonality with the Operational Street Pollution Model[13][14] (OSPM) which in turn forms the basis of the basic street canyon model included in the ADMS-Roads software. Therefore, the AEOLIUS based canyon suite in RapidAir aligns well with industry standards for modelling dispersion of air pollutants in street canyons, in accordance with guidance provided in LAQM .TG(16). The systems of equations used in each street canyon model are provided in Appendix 1.

Street canyon impacts were modelled using the RapidAir AEOLIUS model. Street canyons were identified using building height data sourced from Ordnance Survey (OS) Mastermap data provided by

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[7] Buckland AT and Middleton DR, 1999, Nomograms for calculating pollution within street canyons, Atmospheric Environment, 33, 1017-1036.

[8] Middleton DR, 1998, Dispersion Modelling: A Guide for Local Authorities (Met Office Turbulence and Diffusion Note no 241: ISBN 0 86180 348 5), (The Meteorological Office, Bracknell, Berks).

[9] Buckland AT, 1998, Validation of a street canyon model in two cities, Environmental Monitoring and Assessment, 52, 255-267.

[10] Middleton DR, 1998, A new box model to forecast urban air quality, Environmental Monitoring and Assessment, 52, 315-335.

[11] Manning AJ, Nicholson KJ, Middleton DR and Rafferty SC, 1999, Field study of wind and traffic to test a street canyon pollution model, Environmental Monitoring and Assessment, 60(2), 283-313.

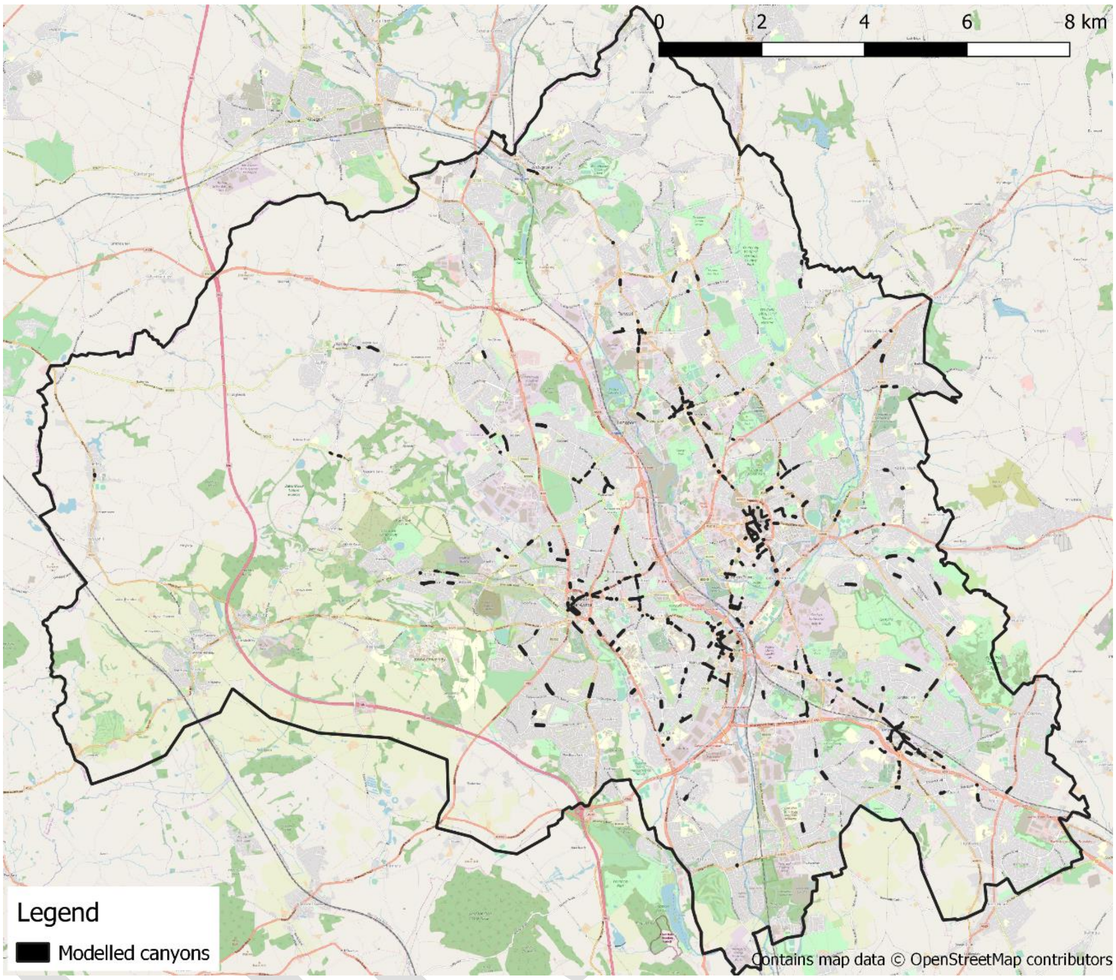
[12] Middleton DR, 1999, Development of AEOLIUS for street canyon screening, Clean Air, 29(6), 155-161, (Nat. Soc for Clean Air, Brighton, UK).

[13] Hertel O and Berkowicz R, 1989, Modelling pollution from traffic in a street canyon: evaluation of data and model development (Report DMU LUFT A129), (National Environmental Research Institute, Roskilde, Denmark).

[14] Berkowicz R, Hertel O, Larsen SE, Sørensen NN and Nielsen M, 1997, Modelling traffic pollution in streets, (Ministry of Environment and Energy, National Environmental Research Institute, Roskilde, Denmark).

the Councils.[15] These canyon locations were then confirmed using Google Street View and local knowledge. Modelled street canyon locations are shown in Figure 2-1.

Figure 2-1: Modelled street canyons



Contains map data © OpenStreetMap contributors

The canyon model is only turned on if the wind is blowing parallel across the canyon (± 5 degrees) i.e. the wind must be between 40 and 50 degrees from the orientation of the canyon. For each hour in the meteorological data with wind direction matching the criteria to turn the street canyon on, the leeward, windward and parallel street canyon concentrations were calculated. To provide annual street canyon concentrations, the sum of the data contained within each of leeward, windward and parallel was calculated.

The results from the street canyon module were subsequently combined with the concentrations modelled in the dispersion step of RapidAir. The annual leeward and annual windward concentrations were added together; this was then added to the dispersion modelled road NO_X. The concentrations from the parallel contribution of the street canyon model were not included as including this would result in double counting of the road NO_X when combined with the dispersion NO_X.

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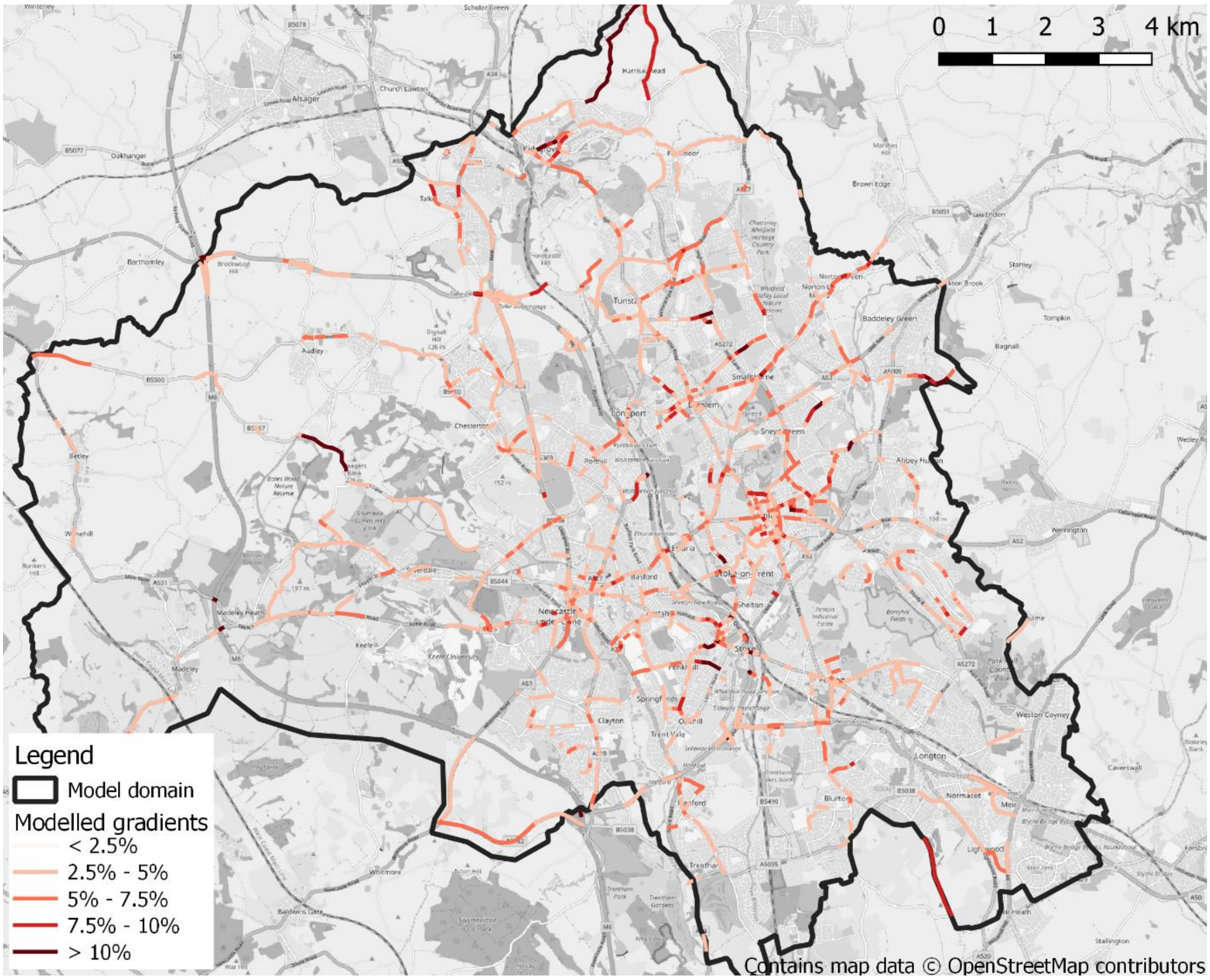
[15] https://www.ordnancesurvey.co.uk/business-and-government/products/mastermap-products.html

2.2.5 Gradients, tunnels and flyovers

Gradient effects were included for relevant road links during emissions calculations. LIDAR Composite Digital Terrain Model (DTM) datasets at 1m resolution are available over the model domain[16]. Link gradients across the model domain were calculated by extracting start and end node elevations for road links from the LIDAR DTM datasets.

The Emissions Factor Toolkit (EFT) v9.1b, provided for the Third Wave Authorities to use by JAQU, includes gradient effects in its emissions calculations, and was used in this assessment. The adjustment in the EfT applies to roads with gradients of 2.5% or greater. Figure 2-2 shows the roads where gradient effects were included during emission calculations.

Figure 2-2: Modelled gradients



No modelling of tunnels or flyovers is included in the modelling, as the RapidAir kernel approach applies the same source height across the model domain as a worst-case estimation of air quality impacts at a height of 2m.

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[16] http://environment.data.gov.uk/ds/survey/#/survey

2.3 Air quality model receptor locations

2.3.1 Monitoring sites

Stoke-on-Trent City Council and Newcastle-under-Lyme Borough Council operate a wide network of monitoring locations comprising both automatic monitoring stations and passive diffusion tube samplers. All available locations where NO_2 monitoring data were measured during 2018 were specified as receptors in the model; and where appropriate, used for model verification and calculating model performance statistics including the Root Mean Square Error (RMSE). A map of the monitoring locations is presented in Figure 2-3; details of these locations are provided in Section 3.

Figure 2-3: Monitoring stations operated in 2018

2.3.2 Roadside receptors and grid

A set of gridded results with a resolution of at least 10m x10m is required by the JAQU guidance. For this study, RapidAir was used to model concentrations at 3m grid resolution. As RapidAir produces concentration grids (in raster format), modelled NO_2 concentrations can be extracted at receptor locations anywhere on the 3m resolution model output grid. For comparison with the PCM model results, annual mean concentrations at a distance of 4m from the kerb and at 2m height were extracted from the RapidAir model outputs at 4m intervals along each road. This provides an assessment of compliance at relevant roadside locations where there may be public access as specified in the Air Quality Directive (AQD) requirements Annex III A, B, and C3.

Annex III of the AQD specifies that macroscale siting of sampling points should be representative of air quality for a street segment of no less than 100 m length at traffic-orientated sites. To provide results for roadside locations, where there is public access and the Directive therefore applies, road links with exceedances of the NO_2 annual mean objective stretching over link lengths of 100m or greater were extracted and presented as a separate GIS layer of model results.

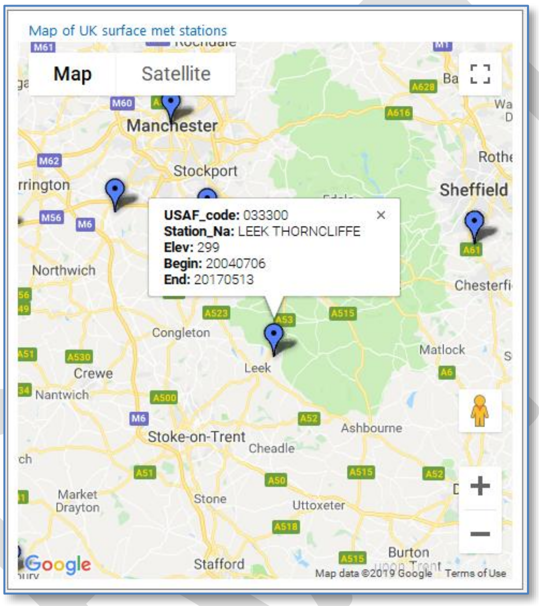
Annex III of the AQD also specifies that microscale sampling should be at least 25 m from the edge of major junctions. Therefore, when reporting model results relevant to compliance with the AQD, locations up to 25m from the edge of major junctions in the model domain were excluded.

3 Modelling methodology

3.1 Base year and meteorological dataset

The modelling used the 2018 annual surface meteorological dataset measured at Leek Thorncliffe (NOAA code 033300) which was processed using RapidAir. RapidAir takes account of upper air data which is used to determine the strength of turbulent mixing in the lower atmosphere; this was derived from the closest radiosonde site and combined with the surface data using the USEPA AERMET model. Where necessary data filling was used following USEPA guidance which sets out the preferred hierarchy of routines to account for gaps. A map showing the location and a wind rose for the 2018 Leek Thorncliffe met dataset are presented in Figure 3-1 and Figure 3-2, respectively.

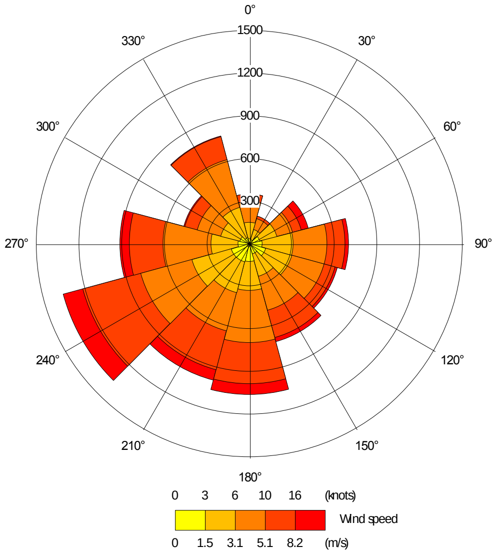
Figure 3-1: Leek Thorncliffe meteorological measurement site location



Map of UK surface met stations

USAF_code: 033300
Station_Na: LEEK THORNCLIFFE
Elev: 299
Begin: 20040706
End: 20170513

Figure 3-2: Windrose from the Leek Thorncliffe meteorological 2018 data



3.2 Road traffic modelling

3.2.1 Emission factors

Emissions from all modelled road traffic sources were calculated using speed-dependent vehicle emission factors for NO_X, primary NO_2, and particulates from the latest version of the Emission Factor Toolkit (EFT), version 9.1b. The emission factors for NO_X and particulates are derived from COPERT, while the emission factors for primary NO_2 are derived from the National Atmospheric Emissions Inventory. COPERT is a European database of emission factors which is recommended for the quantification of road-transport emissions. These factors provide emission factors categorised by vehicle size, age, and Euro classification, taking into account average vehicle mileage and engine degradation.

The EFT uses these factors to calculate emissions along road links given traffic flow, vehicle split, speed, and gradient information.

3.2.2 Traffic flows and speeds

Total traffic flows and average speeds for each model link for 2015 and 2022 were provided by Sweco using a traffic model derived from the North Staffordshire Multi-Modal Model (NSMM) for the following periods:

- AM peak (07:00 to 10:00);
- Interpeak (10:00 to 16:00);
- PM peak (16:00 to 19:00);
- Outside peak (19:00 to 07:00).

These flows and speeds are subject to extensive validation, as detailed in the T2 report. Link flows were compared with two sets of criteria: the GEH statistic, and the Design Manual for Roads and Bridges (DMRB) Vehicle Flow Comparison. Journey time validation was carried out following DfT guidelines, based on those described in WebTAG Unit M3.1 and the DMRB Volume 12, Section 2, Part 1, Chapter 4. The transport model was found to perform within guidelines for both traffic flows and modelled speeds. For validated links, all modelled travel times were found to pass the DRMB criteria of being within 15% or 1 minute of the observed times.

No traffic growth was assumed to occur between the 2015 traffic model base year and the air quality model year of 2018, following advice provided by the Councils.

The traffic model provides vehicle flows for five highway user classes which are: Cars, Taxis, HGVs, LGVs and Buses. A further breakdown of the HGV into rigid and articulated categories was conducted using local traffic count data and ANPR data. Additional traffic from motorcycles was derived using a constant scaling factor of 0.005 for the domain, derived from automatic traffic count data and advice from the Councils. The taxi fleet was split between cars and LGVs based on size data for registered vehicles provided by the Councils.

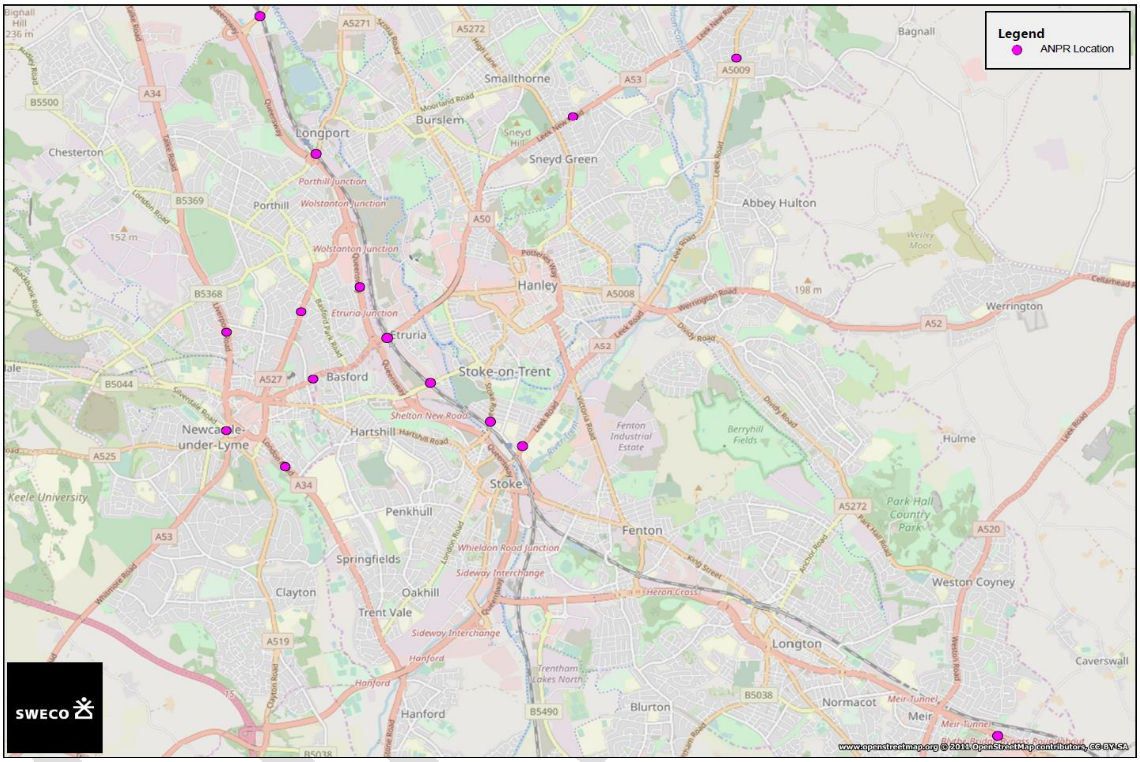
Table 3-1: Size split information from ANPR survey

Vehicle category	Size category	% of total
Taxis	Cars	95.6%
	LGVs	4.4%
HGVs	Rigid (Urban)	71.9%
	Articulated (Urban)	28.1%
	Rigid (Motorway)	39.8%
	Articulated (Motorway)	60.2%

3.2.3 Vehicle fleet composition

Emission calculations for each vehicle category are based on vehicle age split by Euro classification. Results from an ANPR survey were used to derive the vehicle fleet composition for the 2018 base year. For Taxis and private hire, fleet composition was derived from information on licenced vehicles in North Staffordshire provided by Newcastle-under-Lyme Borough Council. The ANPR survey locations are presented in Figure 3-3. Information on the baseline Euro standard mix (traffic composition & age) was collected during ANPR surveys. An average distribution of Euro classifications calculated from the complete ANPR dataset was applied across the entire model domain.

Figure 3-3: ANPR survey locations



Tables 4, 5 and 6 present the fleet age projections for light vehicles, taxis, and heavy vehicles, respectively. Note that Euro standards which are not present in the fleet are not included in the table. The fuel use composition for cars and taxis derived from the ANPR survey is presented in Table 3-5.

Table 3-2: Compliant and non-compliant fleet age splits for 2018, light vehicles

Fleet component	Vehicle type	Pre-Euro 1	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6	Euro 6c
Compliant	**Petrol Car**	-	-	-	-	29%	31%	17%	23%
	Diesel Car	-	-	-	-	-	-	53%	47%
	Petrol LGV	-	-	-	-	57%	8%	25%	10%
	Diesel LGV	-	-	-	-	-	-	59%	41%
	Full Hybrid Petrol Car	-	-	-	-	7%	24%	18%	50%
Non-compliant	**Petrol Car**	1%	1%	5%	92%	-	-	-	-
	Diesel Car	-	-	-	8%	24%	61%	-	-
	Petrol LGV	57%	2%	3%	38%	-	-	-	-
	Diesel LGV	< 1%	< 1%	< 1%	5%	34%	60%	-	-
	Full Hybrid Petrol Car	-	-	-	100%	-	-	-	-

Table 3-3: Fleet age splits for 2018, taxis

Vehicle type	Pre-Euro 1	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6	Euro 6c	Euro 6d
Petrol Car	0.0%	0.0%	0.0%	2.5%	50.8%	44.1%	2.5%	0.0%	-
Diesel Car	0.0%	0.0%	0.0%	2.0%	24.4%	64.4%	9.2%	0.0%	-
Petrol LGV	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	-
Diesel LGV	0.0%	0.0%	1.0%	25.5%	48.0%	21.4%	4.1%	0.0%	-

Table 3-4: Compliant and non-compliant fleet age splits for 2018, heavy vehicles

Fleet component	Vehicle type	Pre-Euro I	Euro I	Euro II	Euro III	Euro IV	Euro V EGR	Euro V SCR	Euro VI
Compliant	**Rigid HGV**	-	-	-	-	-	-	-	100%
	Artic HGV	-	-	-	-	-	-	-	100%
Non-compliant	**Rigid HGV**	0%	0%	1%	13%	24%	15%	46%	-
	Artic HGV	0%	0%	1%	13%	24%	15%	46%	-
All	**Buses / Coaches**	1%	1%	3%	28%	27%	5%	16%	19%

Table 3-5: 2018 fuel split projections for urban cars and taxis

Vehicle	Conventional Petrol %	Full Hybrid Petrol %	Plug-In Hybrid Petrol %	Conventional Diesel %	Full Hybrid Diesel %	Battery EV %
Cars	49.9%	1.6%	0.5%	47.8%	0.1%	0.2%
Taxis	5.1%	-	-	86.0%	4.5%	-

3.2.4 NO_X:NO_2 chemistry

The latest version (7.1) of the LAQM NO_X to NO_2 conversion spreadsheet was used to convert road NOx, f-NO_2 and background NO_X into NO_2 concentrations. The JAQU guidance note for assigning fNO_2 when calculating NO_2 acknowledges that for large model domains and high-resolution models, use of the spreadsheet tool is not practical because the calculator is limited to a maximum of 64.6K lines in the excel spreadsheet. The guidance note recommends the use of the NOx to NO_2 calculator to define statistical relationships between NO_2 concentrations and the input parameters and the use of these relationships to calculate NO_2. This approach was used to calculate the full set of gridded NO_2 results at the 3m resolution.

In this case the statistical relationship was derived using an ordinary least squares (OLS) regression model. The OLS model was derived by defining background NO_X, road NO_X and road fNO_2 as the independent variables, and total NO_2 as the dependent variable.

3.3 Non-road transport modelling and background concentrations

For the 2018 baseline year we have used the 2017 base year LAQM background maps available to download from the Defra UK air web page. The contribution from local road transport source sectors that were modelled explicitly were subtracted from the background maps.

4 Projected future year scenario modelling

4.1 Road transport emissions

The 2022 Reference Case and six 2022 option scenarios were modelled using the following data:

- AM peak, interpeak, PM peak and outside peak traffic flows and speeds provided on a link-by-link basis by Sweco.
- Projections of fleet age and fuel use calculated using the EFT v9.1b fleet projection tool.

4.1.1 Traffic flows and speeds

Traffic flows and speeds matching the specification outlined in Section 3.2.2 were provided by Sweco, separated into “compliant” and “non-compliant” fleet components. Vehicle size splits within the provided categories were assumed to remain constant between 2018 and 2022.

The road geometry for the Etruria Valley Link Road was taken from the Etruria Valley Link Road Consultation documents published by Stoke-on-Trent City Council.[17]

4.1.2 Fleet age projections

The 2022 fleet data was projected from the 2018 fleet data described in Section 3.2.3 using the fleet projection tool in the EFT v9.1b in order to produce a robust local fleet for 2022 based on local data and national projections. Tables 5, 6 and 7 present the fleet age projections for light vehicles, taxis, and heavy vehicles, respectively. Note that Euro standards which are not present in the projected fleet are not included in the table.

Table 4-1: Compliant and non-compliant fleet age splits for 2022, light vehicles

Fleet component	Vehicle type	Euro 3	Euro 4	Euro 5	Euro 6	Euro 6c	Euro 6d
Compliant	**Petrol Car**	-	11.6%	25.4%	15.5%	47.6%	-
	Diesel Car	-	-	-	35.2%	49.8%	15.1%
	Petrol LGV	-	20.9%	31.3%	21.3%	26.5%	-
	Diesel LGV	-	-	-	22.5%	77.5%	-
	Full Hybrid Petrol Car	-	8.0%	8.1%	10.1%	73.9%	-
Non-compliant	**Petrol Car**	100.0%	-	-	-	-	-
	Diesel Car	2.6%	20.2%	77.2%	-	-	-
	Petrol LGV	100.0%	-	-	-	-	-
	Diesel LGV	2.1%	26.6%	71.3%	-	-	-
	Full Hybrid Petrol Car	100.0%	-	-	-	-	-

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[17] https://burslem.info/sites/default/files/pdfs/etruria-valley-link-road-pull-up.pdf?361

Table 4-2: Compliant and non-compliant fleet age splits for 2022, taxis

Fleet component	Vehicle type	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6	Euro 6c	Euro 6d
Compliant	Petrol Car	-	-	20.5%	24.9%	12.4%	42.1%	-
	Diesel Car	-	-	-	-	33.8%	50.8%	15.4%
	Petrol LGV	-	-	100.0%	-	-	-	-
	Diesel LGV	-	-	-	-	59.4%	40.6%	-
Non-compliant	Petrol Car	-	100.0%	-	-	-	-	-
	Diesel Car	-	0.4%	22.2%	77.4%	-	-	-
	Petrol LGV	-	100.0%	-	-	-	-	-
	Diesel LGV	0.2%	8.8%	32.7%	58.3%	-	-	-

Table 4-3: Compliant and non-compliant fleet age splits for 2022, heavy vehicles

Fleet component	Vehicle type	Euro II	Euro III	Euro IV	Euro V EGR	Euro V SCR	Euro VI
Compliant	Rigid HGV	-	-	-	-	-	100.0%
	Artic HGV	-	-	-	-	-	100.0%
	Buses / Coaches	-	-	-	-	-	100.0%
Non-compliant	Rigid HGV	-	6.8%	24.4%	17.2%	51.6%	-
	Artic HGV	1.0%	12.1%	21.0%	16.5%	49.5%	-
	Buses / Coaches	6.9%	37.2%	29.5%	6.6%	19.8%	-

The fuel use composition for cars and taxis derived from the ANPR survey for 2018 was projected to 2022 using the “Petrol/Diesel Projection Tool” provided in the EFT v9.1b. This tool provides separate splits for urban roads, rural roads and motorways; all roads in the model domain were classified as “urban” or “motorway” due to the built-up nature of the model domain. Table 4-4 presents the projected fuel split use for cars and taxis for 2022.

Table 4-4: 2022 fuel split projections for urban cars and taxis, compliant and non-compliant vehicles

Vehicle	Fleet component	Conventional Petrol %	Full Hybrid Petrol %	Plug-In Hybrid Petrol %	Conventional Diesel %	Full Hybrid Diesel %	Battery EV %
Cars	Urban compliant	50.7%	5.7%	3.1%	37.8%	1.2%	1.5%
	Urban non-compliant	48.8%	0.0%	0.0%	51.2%	0.0%	0.0%
	Motorway compliant	53.1%	5.2%	2.7%	36.1%	1.5%	1.5%
	Motorway non-compliant	51.2%	0.0%	0.0%	48.8%	0.0%	0.0%
Taxis	Urban compliant	3.9%	11.9%	2.5%	79.2%	1.2%	1.4%
	Urban non-compliant	3.4%	0.0%	0.0%	96.6%	0.0%	0.0%
	Motorway compliant	6.6%	11.3%	2.0%	77.2%	1.5%	1.4%
	Motorway non-compliant	5.8%	0.0%	0.0%	94.2%	0.0%	0.0%

Appendix 1 - RapidAir street canyon equations

AEOLIUS/OSPM

There are three principal contributions in the AEOLIUS model, a direct contribution from the source to the receptor, a recirculating component within a vertex caused by winds flowing across the top of the canyon, and the urban background. The RapidAir model only take the recirculating component from the canyon and sums this with the kernel derived concentrations.

The RapidAir implementation of AEOLIUS is written in python 2.7 and uses the same equations described in the referenced Met Office papers.

During the coding of the canyon model we tested the outputs of our code with calibration data provided with the FORTRAN version of AEOLIUS. Our implementation agrees almost perfectly ($R^2 = 0.97$) with the version supplied by the Met Office (which is in any case now out of circulation).

The AEOLIUS model is more complex than the STREET model. Concentrations are calculated for the windward and leeward sides of the road using the equations detailed below (based on equations from the Met Office). The leeward and windward concentrations described below are only calculated for streets that are perpendicular to the direction of the wind. Concentrations are calculated in ppb, and for NOx/NO_2 models are converted to µg/m^3 by multiplication by 1.91. The system of equations in Rapid Air's implementation of the AEOLIUS model are shown below.

Inputs:

Emission rates (Q, µg/m/s); traffic speeds (v_t, mph), traffic density (f, vehicles per hour), % of cars and heavy good vehicles (f_c and f_h respectively), wind speed at roof level (u_r, m/s), street canyon width (w, m), street canyon height (h, m), and angle of street (θ).

Leeward concentrations:

The leeward concentrations = sum(C_{dlee} + C_{rec}) where C_{dlee} is the direct contribution from vehicles and C_{rec} is the pollution associated with recirculation.

Direct contribution (C_{dlee}):

$$Recirculation\ zone\ (l_r) = \min\left(w, l_v * \sin(\theta)\right) \qquad \text{(meters)}$$

Where:

$$vortex\ length\ (l_v) = 2 * r * h \qquad \text{(meters)}$$

And r = wind speed dependence factor = 1 if u_r > 2 m/s and = $u_r/2$ otherwise.

If the recirculation zone is greater than the width of the canyon:

$$C_{dlee} = \sqrt{\frac{2}{\pi} * \frac{Q}{(w * \sigma_w)} * \ln\left[\left(\frac{\sigma_w * w}{h_o * u_s}\right) + 1\right]}$$

Where:

σ_w = mechanical turbulence from wind and traffic (m/s) = $\sqrt{(\lambda * u_s)^2 + {\sigma_{wo}}^2}$

λ = constant for removal at the top of the canyon = 0.1

σ_{wo} = traffic-created turbulence (m/s) = $b * \sqrt{\frac{v_t * f_c * s_c + v_t * f_h * s_h}{w}}$

where s_c = mean surface area of cars (4 m^2), s_h = mean surface area of heavy vehicles (16 m^2) and b = aerodynamic constant (0.18)

u_s = wind speed at street level (m/s) = $u_r \left(\frac{\ln\left(\frac{h_o}{z_o}\right)}{\ln\left(\frac{h}{zo}\right)} \right) (1 - d * \sin(\theta))$

h_o = effective height of emissions (2 m)

z_o = effective roughness length (0.6 m)

d = model dependence (0.45)

If the recirculation zone is less than the width of the canyon:

$$C_{dlee} = \sqrt{\frac{2}{\pi}} \frac{Q}{(w * \sigma_w)} \left[ln\left[\left(\frac{\sigma_w * d_1}{h_o * u_s} \right) + 1 \right] + R * \ln \left(\frac{h_o + \sigma_w * \frac{d_6}{u_s}}{\frac{\sigma_w * l_r}{u_s} + h_o} \right) + \frac{\sigma_w}{\omega_t} \left[1 - e^{\left(\frac{-\omega_t d_7}{u_s h} \right)} \right] \right]$$

Where:

d_1 (m) = min(w, l_r)

R = max(0, C_{ang})

C_{ang} = cos(2*r* θ)

d_6 (m)= min(max(l_{max}, l_r), x_1)

l_{max} = w/sin(θ)

x_1 = vertical distance (m) at which pollutants can escape canyon = $\frac{u_s(h - h_o)}{\sigma_w}$

ω_t = removal at top of the canyon (m/s) = $\sqrt{(\lambda * u_r)^2 + 0.4(\sigma_{wo})^2}$

d_7 (m) = max(l_{max}, x_1)-x_1

Recirculation contribution (C_{rec}):

$$C_{lee} = \frac{\left[\left(\frac{Q}{W} \right) d_1 \right]}{\omega_t * d_2 + \omega_s * d_3}$$

Where

d_2 (m) = min(w, 0.5*l_r)

d_3 (m) = $l_s \left(\max\left(0, \frac{2w}{l_r} - 1\right) \right)$

l_s (m) = $\sqrt{(0.5 * l_r)^2 + h^2}$

ω_s = removal speed at the side of the canyon (m/s) = $\sqrt{{u_s}^2 + {\sigma_{wo}}^2}$

Windward concentrations (C_{dwind}):

Final windward concentrations = $C_{dwind} + C_{rec}$. $C_{dwind} = 0$ if $l_r \geq w$, else:

$$C_{dwind} = \sqrt{\frac{2}{\pi}} \frac{Q}{w * \sigma_w} \left[ln \left(\frac{\sigma_w + d_4}{u_s + h_o} + 1 \right) + \frac{\sigma_w}{\omega_t} \left[1 - e^{\left(\frac{-\omega_t d_5}{u_s h} \right)} \right] \right]$$

d_4 (m) = min[(w – l_r), x_1]

d_5 (m) = [max[(w – l_r),x_1]]-x_1

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