APPENDIX 2

Southampton Clean Air Zone – Air Quality Modelling Methodology Report (AQ2)

Report for Southampton City Council

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Southampton City Council

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Southampton CAZ Feasibility Study

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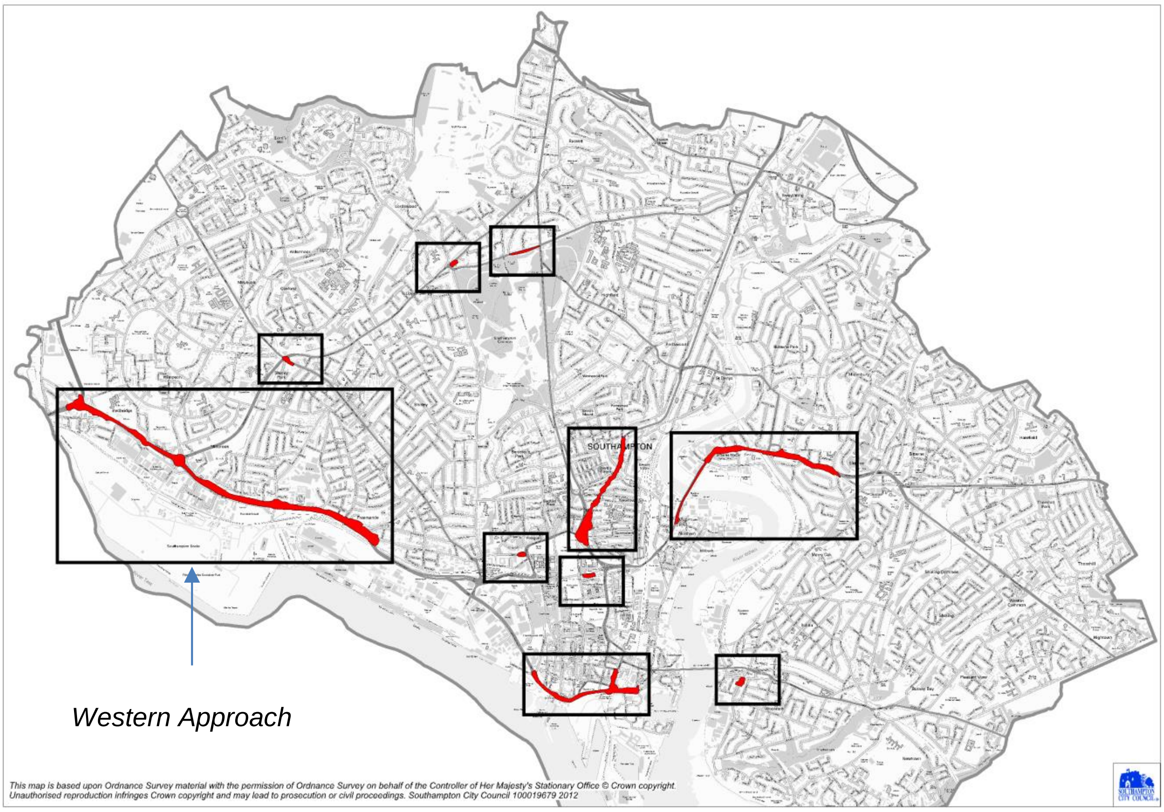
1 Introduction and outline modelling scope

Southampton City Council is one of the initial five cities that were required to carry out a Clean Air Zone (CAZ) Feasibility Study by the Government for non-compliance with the NO_2 limit values. Subsequently to this a small exceedance area was also identified in New Forest District Council adjoining Southampton, and the Councils were instructed to work jointly to assess the impact a potential CAZ in Southampton on the New Forest exceedance location. This report sets out the Air Quality modelling methodology used for this study covering both Southampton and New Forest.

1.1 Background

Southampton like many other urban areas, has elevated levels of Nitrogen Dioxide (NO_2) due mainly to road transport emissions. Emissions from the port also contribute significantly in key locations. As such Southampton City Council (SCC) has designated 10 Air Quality Management Areas (AQMA) across the City where concentrations of NO_2 breach Government, health-based air quality objectives as shown in Figure 1.

Figure 1 Southampton Air Quality Management Areas (AQMA)



At the national level the EU has commenced infraction proceedings against the UK Government and Devolved Administrations for their failure to meet the EU Limit Value for NO_2. In 2015, the Supreme Court ordered the Government to consult on new air pollution plans that had to be submitted to the European Commission no later than 31 December 2015. As such DEFRA released plans[1] to improve

[1] https://www.gov.uk/government/publications/air-quality-in-the-uk-plan-to-reduce-nitrogen-dioxide-emissions

air quality, specifically tackling NO_2, in December 2015. The Plans identify 5 cities outside London, including Southampton, where the EU Limit Value for NO_2 are not expected to be met by 2020. The Plans state that each of the cities identified will be legally required to introduce a formal charging-based Clean Air Zone (CAZ) for specified classes of vehicles and European Vehicle Emission Standards (Euro Standards) as soon as practical but no later than 2020.

The key area identified by the DEFRA plan that will exceed in 2020 is the Western Approaches AQMA. This area was the focus of a study on a Low Emission Zone undertaken by Southampton City Council in 2014[2]. The study showed that road transport emissions accounted for between a third and two thirds of modelled levels of NOx in certain locations and port activities contributed to a third of levels at Millbrook.

Building on the 2014 study Southampton commissioned a wider based Low Emission Strategy study to assess options for reducing emissions from transport across the city. This study provided the basis for Southampton's approach to developing a Clean Air Zone, based on cost benefit assessment of potential emission reduction measures. The study set out a potential charging Clean Air Zone and a range of non-charging or supporting measures.

Subsequent work by DEFRA updated its air quality plan using more recent information on the expected real-world emission performance of vehicles. This latest analysis is suggesting that emission from vehicles will be higher than previously estimated and so breaches of the air quality limits are likely to persist for longer and over a wider area. This later analysis identified an exceedance area in neighbouring New Forest District Council that would be expected to be beneficially impacted by a CAZ in Southampton. As such NFDC were instructed to work jointly with Southampton City Council to assess the impact of the CAZ options being developed on the New Forest exceedance area.

1.2 Outline scheme options

The Low Emission Strategy (LES) study developed a package of measures to reduce emissions covering all key transport modes in the city: cars, freight, buses and taxis. This has formed the basis of the city wide Clean Air Zone that Southampton is pursuing, and although a formal Low Emission Zone (or charging CAZ) was not assessed in the study, potential elements of such a scheme were considered including:

- Euro VI standards for city centre deliveries
- A ULEV standard (Euro VI plus 30% lower CO2) for buses on key bus corridors
- Emission standards in taxi licensing

These elements would effectively constitute a class B CAZ based mainly around the city centre. In addition, specific measures were considered for targeting vehicle movements to and from the port. In developing these measures consultation was carried out with key stakeholders within the city council and with key external stakeholders such as the bus and freight companies and neighbouring authorities.

In defining options for the charging CAZ a long list of options has been considered and sifted down to a short list of 3 options for detailed assessment. The long list options considered are presented in Table 1. This was considered to provide a range of scheme options for a charging CAZ to allow for sifting and selecting the most appropriate. The potential boundaries are illustrated in Figure 2.

[2] Low Emission Zone Feasibility Study, Western Approaches, Ricardo AEA/LES Ltd 2014

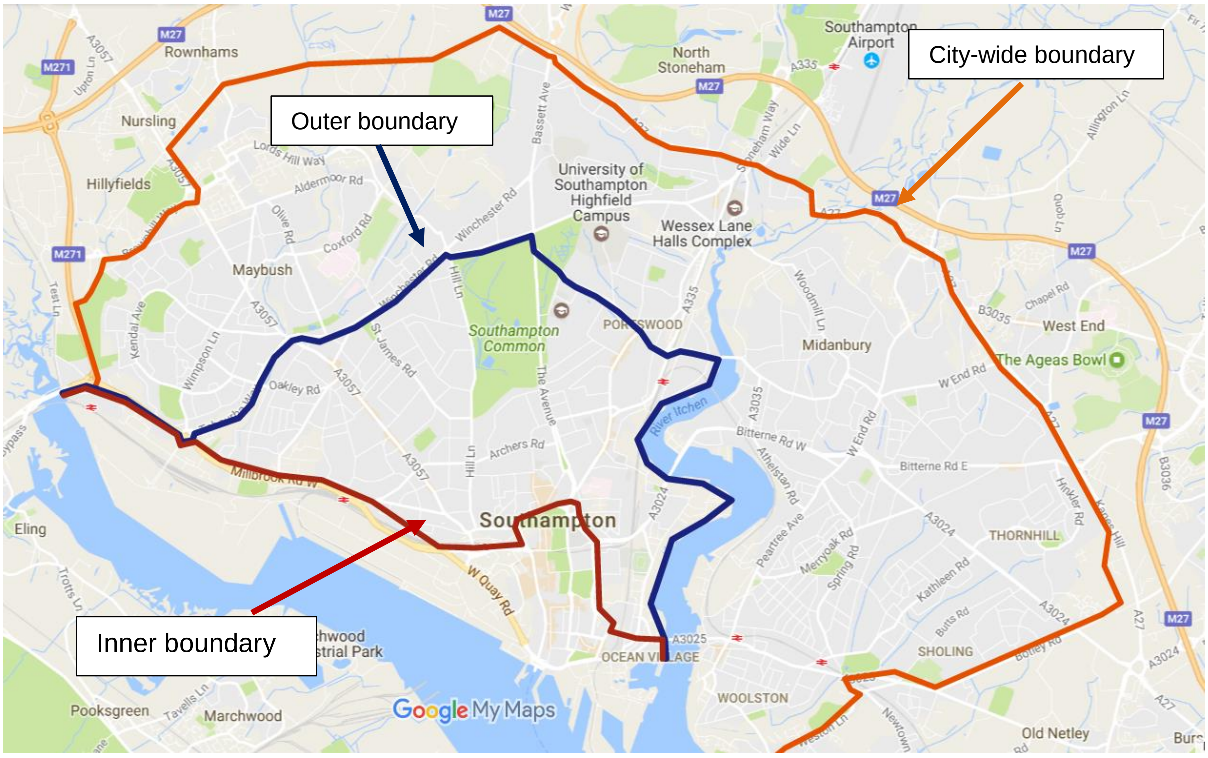
Table 1 – Long-list of CAZ options

	Scenario	Red Citywide	Blue Outer RR	Brown WA+CC inc Inner RR	Brown WA+CC exc Inner RR	Brown CC inc Inner RR	Brown CC exc Inner RR
1	Citywide B	B					
2	Citywide C	C					
3	Citywide D	D					
4	OuterRR B		B				
5	OuterRR C		C				
6	OuterRR D		D				
7	Inner WA+CC (Inc InnerRR) B			B			
8	Inner WA+CC (Inc InnerRR) C			C			
9	Inner WA+CC (Inc InnerRR) D			D			
10	Inner WA+CC (Exc InnerRR) B				B		
11	Inner WA+CC (Exc InnerRR) C				C		
12	Inner WA+CC (Exc InnerRR) D				D		
13	Citywide Doughnut BD	B				D	
14	Citywide Doughnut BC	B				C	

The sifting of the long list was based on simplified transport model runs covering:

- Changes in flows of compliant and non-compliant vehicles, weighted by average emissions, to provide an estimate of change in emissions:
- Transport impacts covering: change in total vkm on the network, Change in travel time on the network, change in delays at key junctions
- Simplified ranking of costs and revenues

Figure 2 Illustrative CAZ boundaries



As well as the charging CAZ potential packages of non-charging measures are being considered. These non-charging measures are based on the existing LES work and planned investment. The final four options that were agreed for assessment are:

- Option 1 – a citywide Class B CAZ;
- Option 1a – a city wide HGV charging scheme complemented by a buss traffic condition based on Euro VI for the city centre and incentives to upgrade taxis;
- Option 2 – a city centre Class A CAZ, complemented by bus retrofit grants, taxi upgrade incentives a expansion of the freight consolidation centre and related DSP initiative and worth with the port on promoting Euro VI HGVs
- Option 3 – a non-charging CAZ comprising a bus traffic condition for Euro VI buses in the city centre supported by retrofit grants, taxi upgrade incentives and the freight measures from option 2.

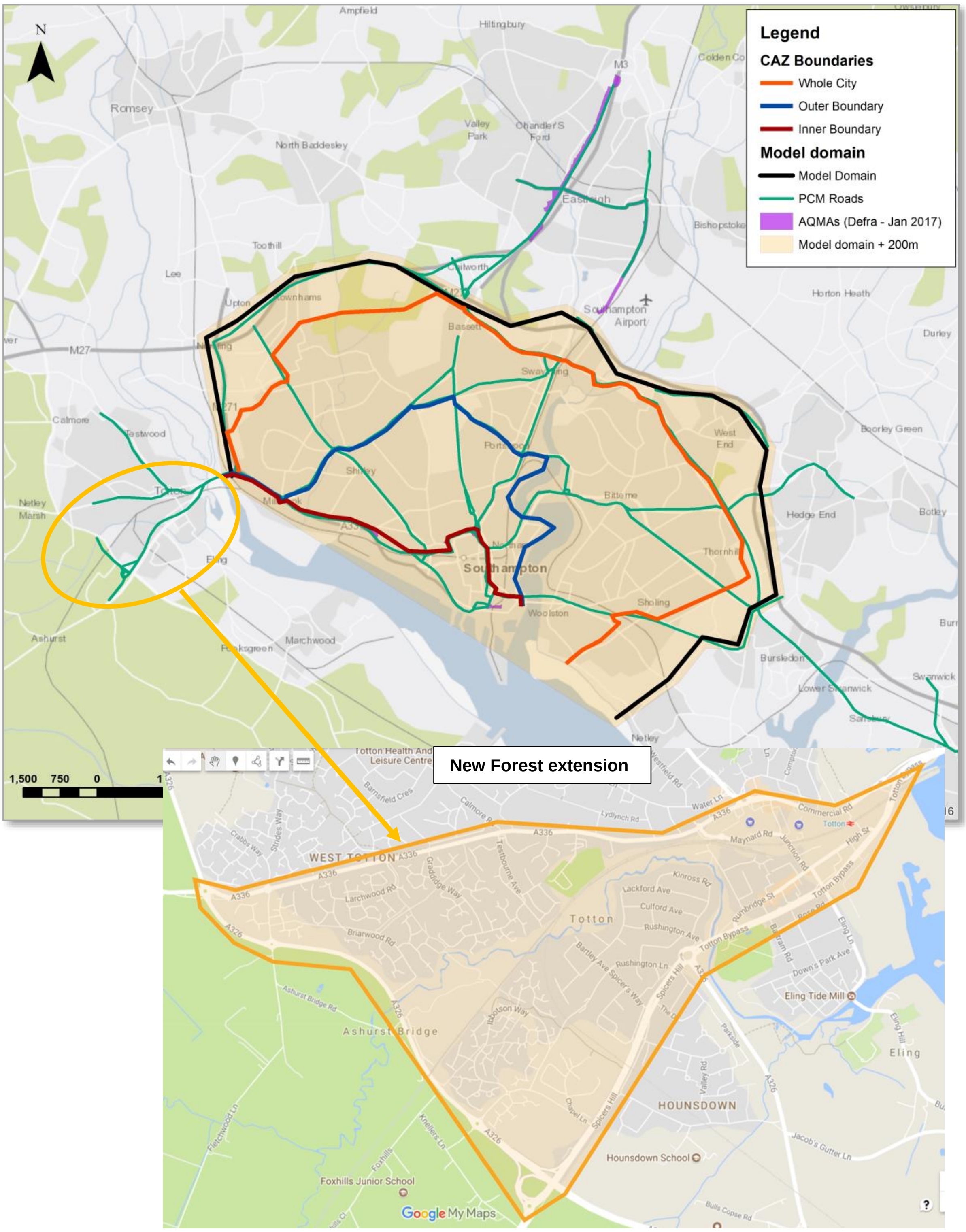
1.3 Modelling domain and years

In carrying out the modelling of the transport and air quality impacts of the scheme a model domain is required that covers the scheme options, relevant AQMAs and potential diversion routes. Therefore, the proposed model domain shown in Figure 3 has been chosen to cover the following:

- All the AQMAs in Southampton including the main area of concern from the national modelling assessment along the Western Approach;
- The wider transport network out to and including the M27 and M271 which will cover all the likely key diversion routes should vehicles seek to avoid the AQMA

In addition to this core modelling domain for Southampton we have extended the domain to cover the expected exceedance area in New Forest and surrounding roads. This additional area is illustrated in map extension in Figure 3. Further details in relation to the model domain are provided in section 2 of the air quality modelling assessment.

Figure 3 Model domain



There will be two key model years used in the modelling work: a 2015 base year and a target implementation year for the CAZ of 2020. The base year is taken as 2015 as this covers the latest air quality and transport data, and is the base year of the transport model being used. In addition, we have interpolated interim years between 2015 and 2020.

Table 2 Model years

Year	Description
2015	**Base year** – using latest available data on air quality and transport.
2016-2019	**Interim years** – interpolated between the base and implementation year.
2020	**Implementation year** – latest date when CAZ scheme is due to be in place.

1.4 Background modelling

The primary cause of the air pollution problems in Southampton and New Forest are related to traffic activity and the impact of the CAZ will be in relation to this traffic activity. As such the focus of the modelling is the transport emissions. However, there are several other background sources that are important, particularly in Southampton, and will need to be covered specifically in the modelling work:

- Emissions from port related activity – including both vessels and onshore port activity;
- Industrial emissions related to the Viridor incinerator and the gas power station both located just opposite the port in the Marchwood industrial site.

The details of how these sources have been treated, particularly the port, and their relation to the wider background is described in section 4.3.

2 Details of the Modelling Domain

The core air quality model domain covers the area of Southampton bounded by the M271 and M27 motorways to the north and west (but includes these links), and extends south to Southampton Water and east as far as Netley. In addition to the core model domain we have included are area of New Forest bounded by the A336 to the North, the Totton Bypass and Spicers Hill to the south and the A326 to the West.

Displacement of traffic due to the implementation of CAZ measures is not expected to occur beyond the proposed model domain and the sub-regional traffic model proposed to support the study (discussed in 'Transport Modelling Methodology Report' and built and run by SYSTRA) has been chosen as it fully encompasses the affected areas.

A map showing the extent of the air quality domain relative to the proposed CAZ zones and the associated traffic model network is presented in Figure 4. A map showing the model domain relative to roads included in the national Pollution Climate Mapping (PCM) model is presented in Figure 5. All road links in the PCM model pertinent to Southampton are included in the model domain specification.

Southampton City Council has declared 10 Air Quality Management Areas (AQMA's) across the city to date, all of which are within the proposed model domain. A map showing the locations of the AQMA's relative to the model domain is presented in Figure **6**

All of Southampton City Council's 2015 NO_2 roadside measurements will be used in the air quality modelling assessment to verify the model outputs, assuming data capture and QA/QC are satisfactory for the 2015 baseline year. A map showing the sites at which NO_2 concentrations were measured during 2015 is presented in Figure 7.

Figure 4: CAZ study domain and relationship to SYSTRA's sub-regional transport model links

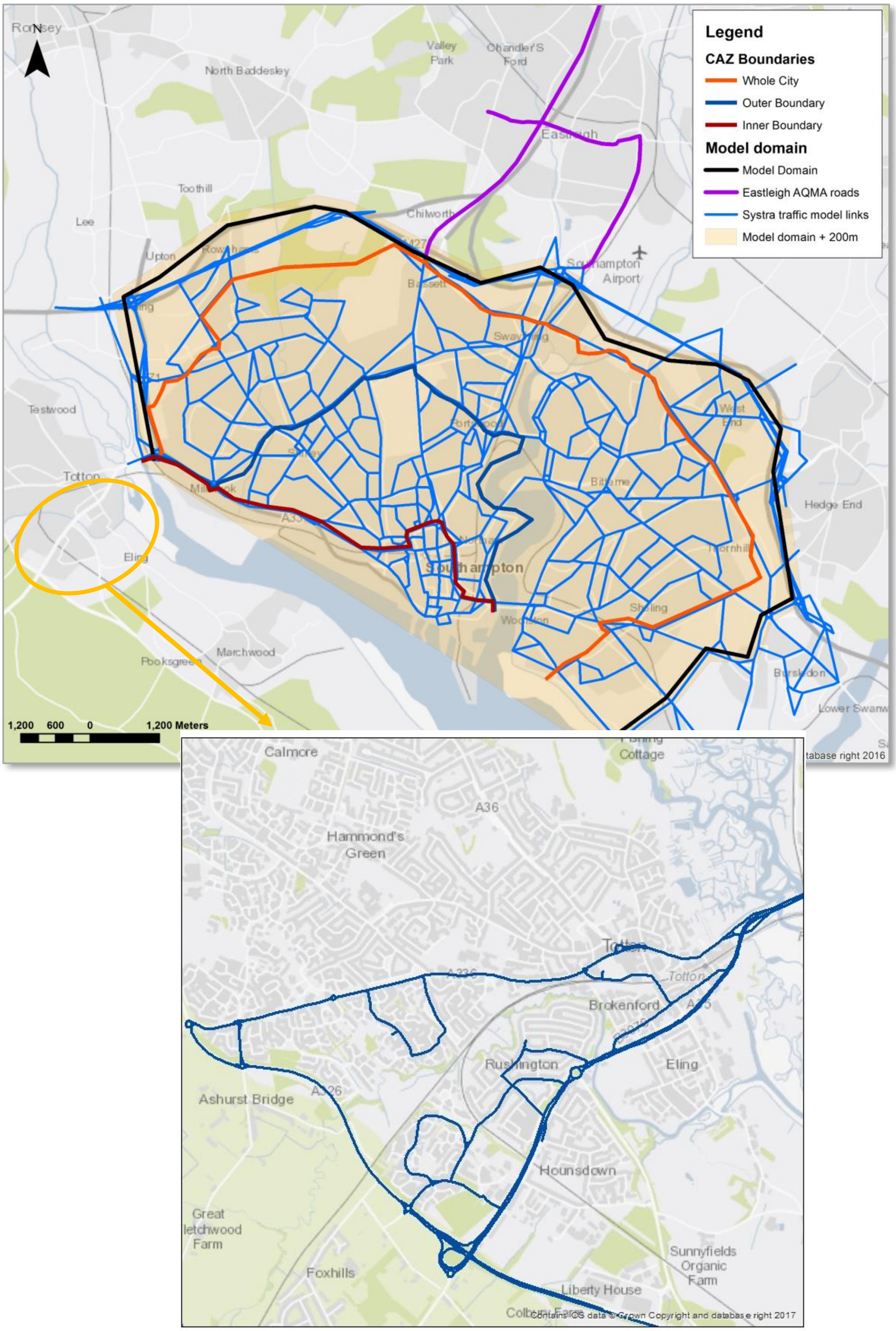


Figure 5: PCM model road links within the CAZ study domain 2015

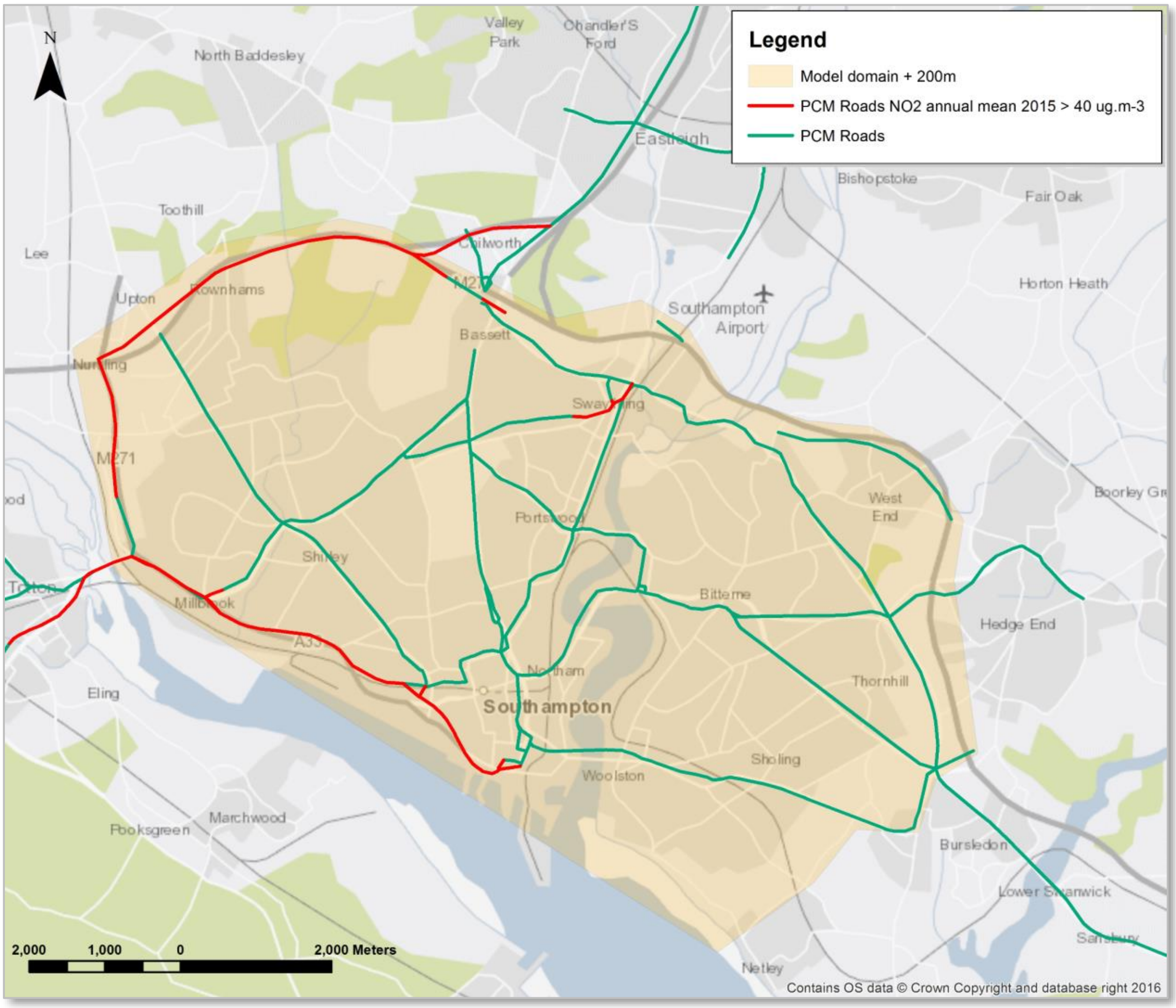


Figure 6: Southampton City Councils AQMA locations

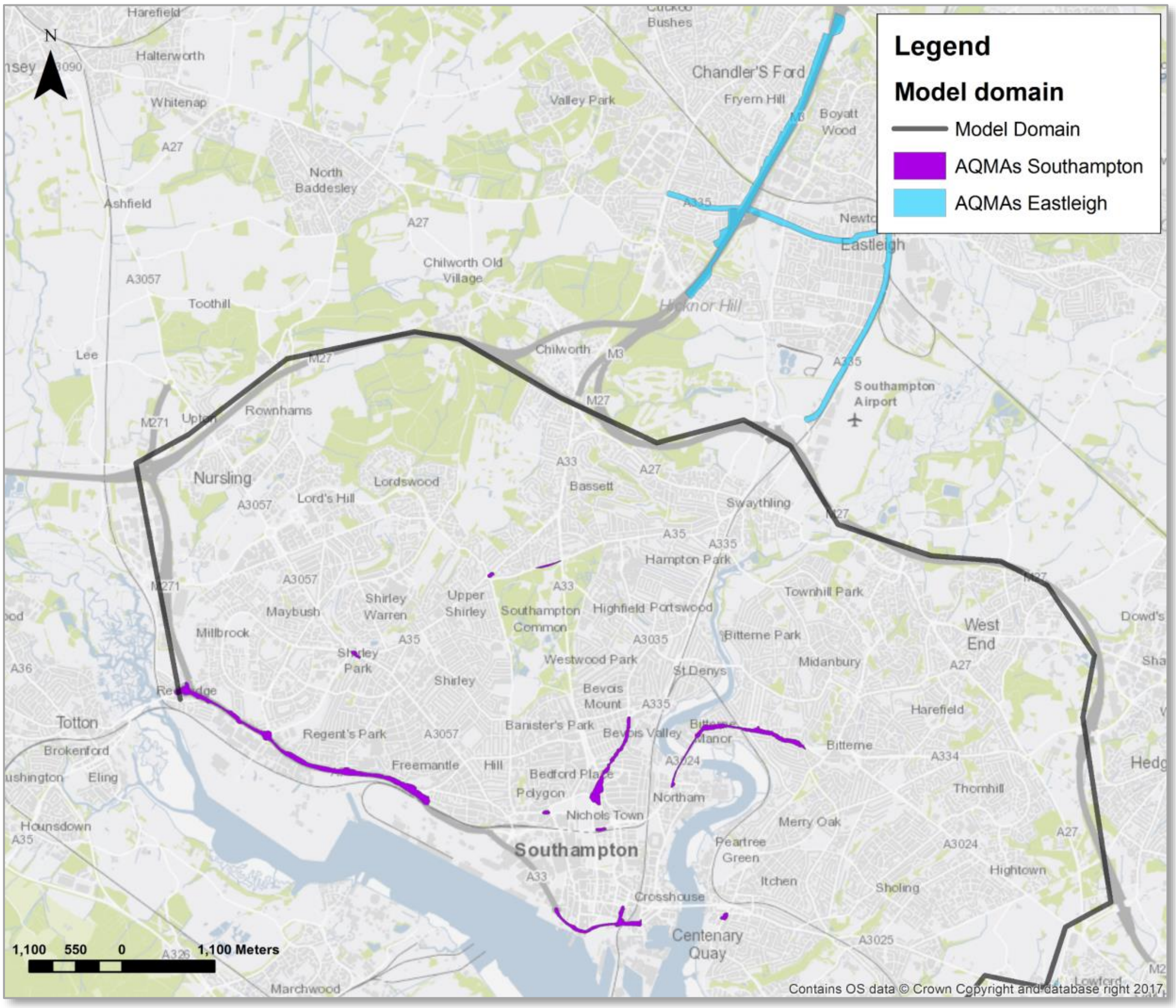
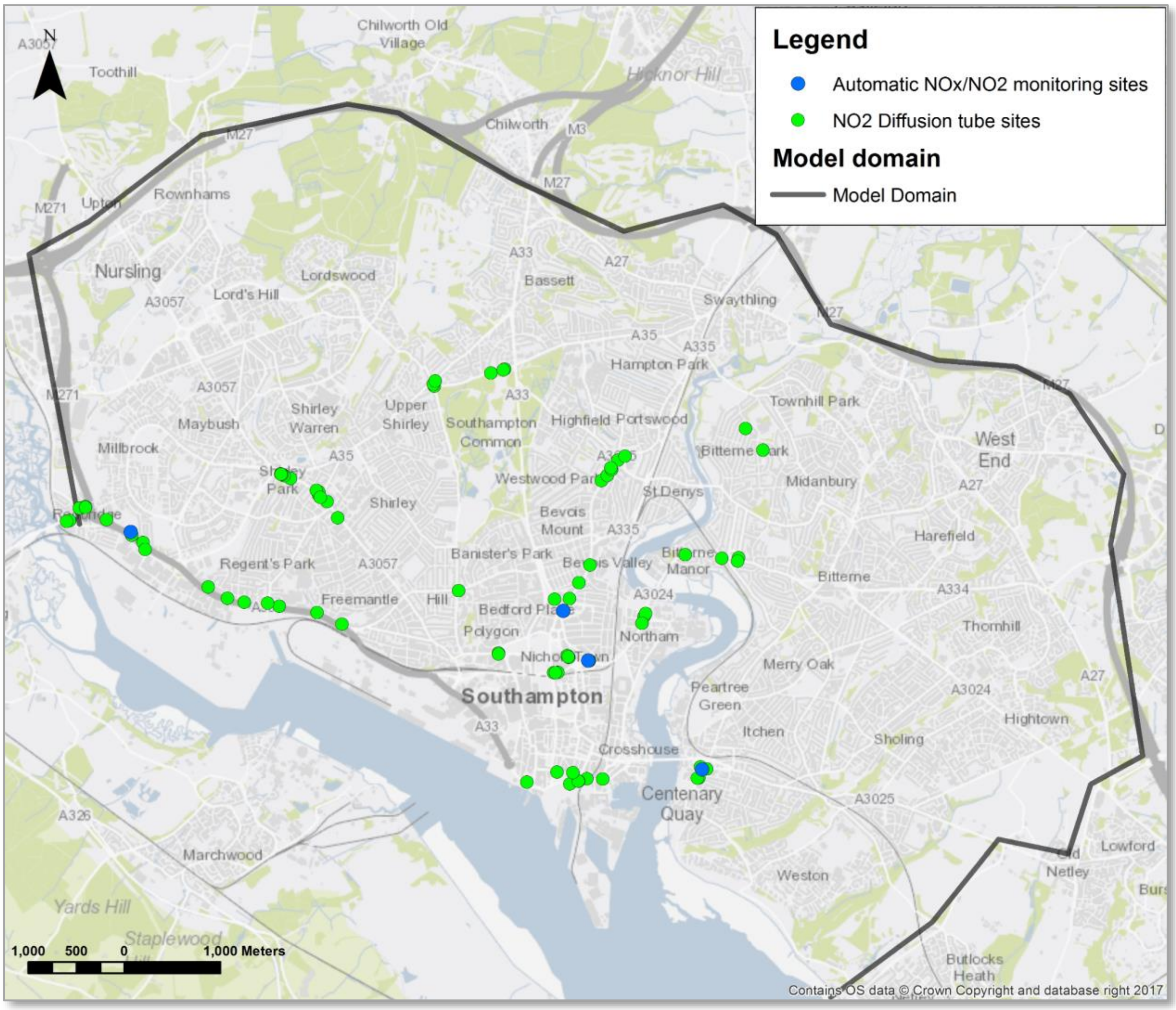


Figure 7 Southampton City Council NO_2 monitoring sites 2015



3 Model and receptor location selection

3.1 Dispersion model

We have used the RapidAir modelling system for the study. This is Ricardo Energy & Environment's proprietary modelling system developed for urban air pollution assessment and the model that was used previously in Southampton for the LES study. The compliance assessment for this model against the JAQU requirements is set out in Air Quality Tracker table th table with further description of the model 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

[3] https://www3.epa.gov/ttn/scram/dispersion_prefrec.htm#aermod

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 USEPA have very strict guidelines on use of dispersion models and in fact the use of AERMOD is written into federal law in 'Appendix W' of the Guideline on Air Quality Models[5]. The RapidAir model uses AERMOD at its core and is evidently therefore based on sound principles given the pedigree of the core model.

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[6]. 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 paper is currently being finalised for publication with our partners at Strathclyde University in a suitable journal (most likely Atmospheric Environment).

3.2 Core aspects of the modelling

3.2.1 Chemistry, meteorology and topology

NOx to NO_2 chemistry was modelled using the Defra NOx/NO_2 calculator. Modelled annual mean road NOx concentrations were combined with background NOx and a receptor specific (i.e. at each receptor) fNO_2 fraction to calculate NO_2 annual mean concentrations. The receptor specific fNO_2 fraction was calculated by dividing the modelled road NOx by modelled road NO_2 at each receptor.

3.2.2 Meteorology

Modelling was conducted using the 2015 annual surface meteorological dataset measured at Southampton Airport. The dataset was processed in house using our own meteorological data gathering and processing system. We use 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 process 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 difference between the meteorological site and the dispersion site, surface parameters at the met site were included as recommended in the guidance and the urban option specified for the dispersion site.; land use parameters were accessed from the CORINE land cover datasets[7].

A uniform surface roughness value of 1.0 m was modelled to represent a typical city/urban environment.

[4] https://www.epa.gov/state-and-local-transportation/project-level-conformity-and-hot-spot-analyses
[5] 40 CFR Part 51 Revision to the Guideline on Air Quality Models: Adoption of a Preferred General Purpose (Flat and Complex Terrain) Dispersion Model and Other Revisions; Final Rule, Environmental Protection Agency, 2005
[6] https://uk-air.defra.gov.uk/research/air-quality-modelling?view=intercomparison

[7] EEA (2018) https://www.eea.europa.eu/publications/COR0-landcover

3.2.3 Canyon modelling

The platform includes two very well-known street canyon algorithms with significant pedigree in the UK and overseas. The first replicates the functionality of the USEPA 'STREET' model. The code was developed by the Office of Mobile Source Air Pollution Control at the USEPA and published in a series of technical articles aimed at operational dispersion modellers in the regulatory community[8,9]. The STREET model has been used for many years and has been adopted in dispersion modelling software such as AirViro. The USEPA canyon model algorithms are essentially the same as those recommended by the European Environment Agency for modelling canyons in compliance assessment[10].

The RapidAir model also 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[11]. The scientific basis for the model is presented in a series of papers by the Met Office[12,13,14,15,16.] The model formulation shares a high level of commonality with the Operational Street Pollution Model[1718] (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.

The systems of equation used in each street canyon model are provided in Appendix 3.

3.2.4 Gradient, tunnels and flyovers

Gradient effects have been included for relevant road links during emissions calculations. LIDAR Composite Digital Terrain Model (DTM) datasets at 1m and 2m resolution are available over the proposed model domain[19]. Link gradients across the model domain can be calculated using GIS spatial analysis of LIDAR DTM datasets.

The method described in TG(16) provides a method of adjusting road link emission rates for gradients greater than 2.5%; it is applicable to broad vehicle categories for heavy vehicles only. As per the guidance and clarification provided by JAQU this adjustment has been applied to all pre Euro VI HGVs and buses.

No modelling of tunnels or flyovers was included as the RapidAir kernel approach applies the same source height across the model domain. If modelling of flyovers was considered to be beneficial for this assessment, we could have modelled road link at a higher elevation using a dispersion kernel created with a different source height in AERMOD. It was not however considered beneficial to do this for this assessment.

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[8] Ingalls., M. M., 1981. Estimating mobile source pollutants in microscale exposure situations. US Environmental Protection Agency. EPA-460/3-81-021
[9] USEPA Office of Air Quality Planning and Standards., 1978. Guidelines for air quality maintenance planning and analysis, Volume 9: Evaluating indirect sources. EPA-450/4-78-001
[10] http://www.eea.europa.eu/publications/TEC11a/page014.html
[11] Buckland AT and Middleton DR, 1999, Nomograms for calculating pollution within street canyons, Atmospheric Environment, 33, 1017-1036.
[12] 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).
[13] Buckland AT, 1998, Validation of a street canyon model in two cities, Environmental Monitoring and Assessment, 52, 255-267.
[14] Middleton DR, 1998, A new box model to forecast urban air quality, Environmental Monitoring and Assessment, 52, 315-335.
[15] 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.
[16] Middleton DR, 1999, Development of AEOLIUS for street canyon screening, Clean Air, 29(6), 155-161, (Nat. Soc for Clean Air, Brighton, UK).
[17] 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).
[18] 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).
[19] http://environment.data.gov.uk/ds/survey/#/survey

3.3 Receptor locations

Southampton has a wide network of monitoring locations comprising a mix of passive and active sampling. All available monitoring locations for 2015 will be treated as receptors in the model as the 2015 NO_2 annual mean measurements will be used for model verification and producing model performance statistics. A map of these monitoring locations is shown above in Figure 7 in relation to the modelling domain. In addition we have used monitoring data that is available in the New Forest modelling domain as both receptor location and for local verification.

The RapidAir model can comfortably deal with about 500 million gridded locations which provides for over 20,000 cells in the 'x' and 'y' axes. We can therefore model 20km x 20km, which is roughly the size of the Southampton modelling domain, down to a 1m resolution. Therefore we have used this 1m resolution for our work in Southampton and New Forest. The canyon model is set to the same resolution as the grid model so that they align perfectly spatially.

As RapidAir produces concentration grids (in raster format), modelled NO_2 concentrations can be extracted at receptor locations anywhere on the 1m resolution model output grid. For comparison with PCM model results, annual mean concentrations at a distance of 4m from the kerb have been extracted from the RapidAir data and presented as a separate model output file. This will allow the selected locations to be assessed according to the Air Quality Directive (AQD) requirements Annex III A, B, and C3.

Southampton has several AQMAs all of which contain numerous residential receptors. RapidAir, by virtue of its very high resolution outputs, can produce discrete estimates at every single residential property in Southampton (every 1m 'square' in actual fact); any location where there is a risk of the objective being exceeded can therefore be included in the modelling and outlined during post processing. There are no AQMAs in the New Forest modelling domain.

To aid interpretation of the outcomes of the study when considering compliance with the air quality directive (AQD), annual mean concentrations at the roadside exceedance locations identified in the PCM model will be extracted from the RapidAir dispersion model results and presented as a separate model output file. Roadside receptor locations in the PCM model are at a distance of 4m from the kerb and at 2m height. A subset of the OS Mastermap GIS dataset provided spatially accurate polygons representing the road carriageway, receptor locations were then placed at 50m intervals along relevant road links using a 4m buffer around the carriageway polygons.

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 relevant to this requirement, for roadside locations where there is public access and the Directive applies; road links with exceedances of the NO_2 annual mean objective stretching over link lengths of 100m or greater can be presented as a separate GIS layer of model results.

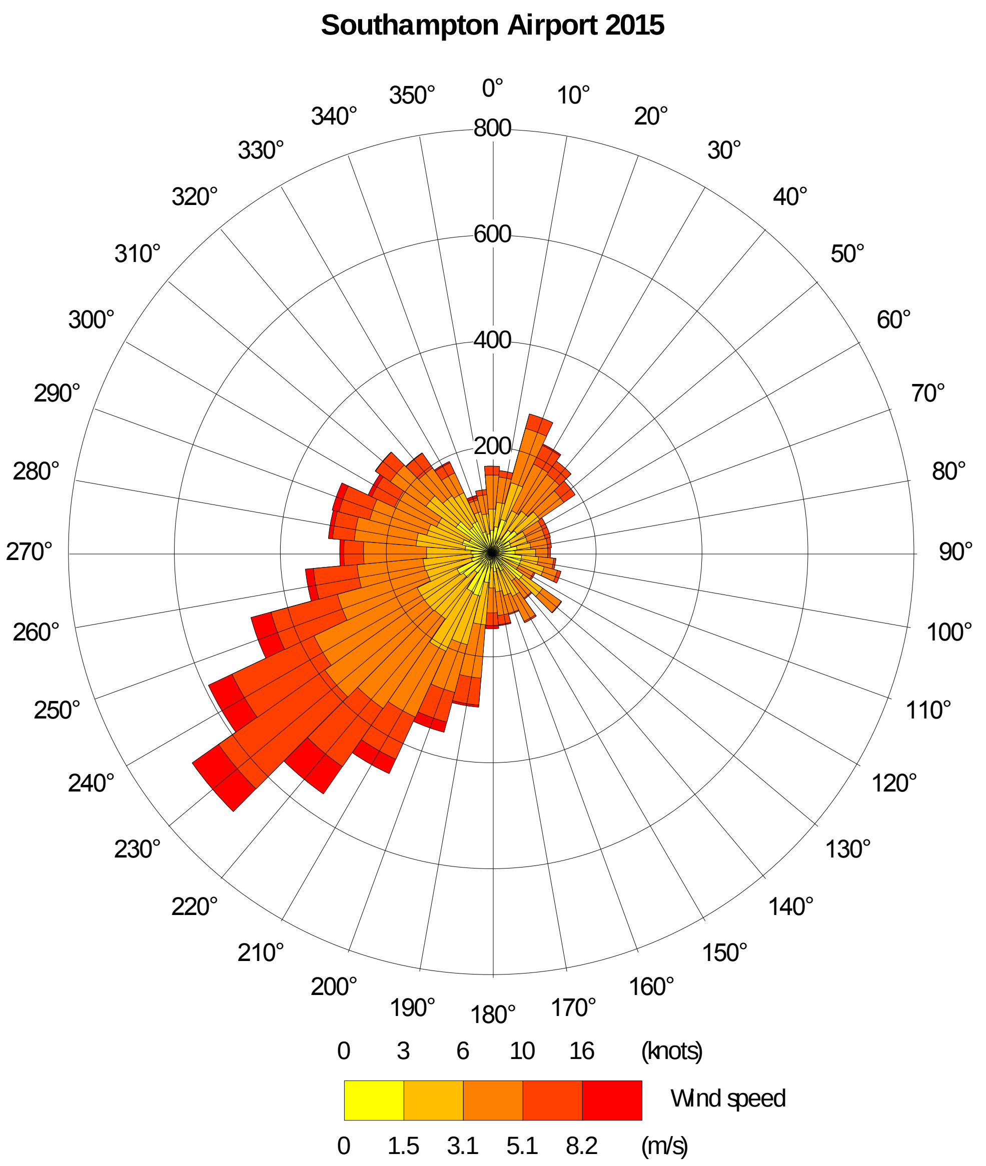
Annex III of the AQD also specifies that microscale sampling should be at least 25 m from the edge of major junctions. When reporting model results relevant to compliance with the AQD, locations up to 25m from the edge of major junctions in the model domain have also been excluded.

4 Base year modelling

4.1 Base year and meteorological dataset

As described in section 1.3 we have modelled a baseline year of 2015. We have used the 2015 annual surface meteorological dataset measured at Southampton Airport which has been processed in house using our own meteorological data gathering and processing system. We use open 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; we have derived this from the closest radiosonde site and process with the surface data in the USEPA AERMET model. Where necessary we have utilised data filling following USEPA guidance which sets out the preferred hierarchy of routines to account for gaps (persistence, interpolation, substitution). A wind rose for the 2015 Southampton airport met dataset is presented in Figure 8.

Figure 8: Windrose

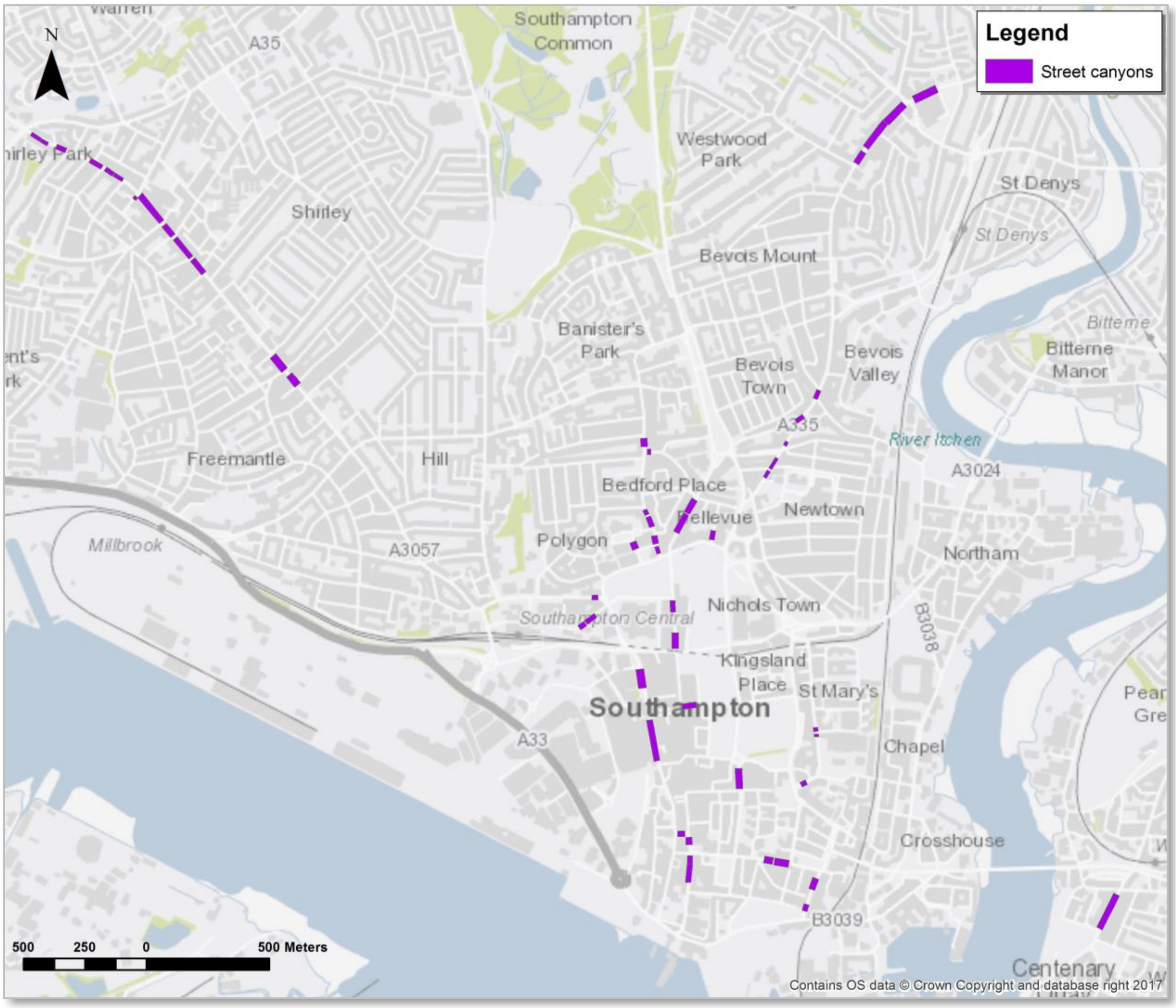


4.2 Representation of road locations and canyons

A realistic representation of road locations has been modelled by assigning emissions to the road links represented in the Ordnance Survey ITN Roads GIS dataset; it contains spatially accurate road centreline locations for various road categories e.g. Motorway, A road, B road, minor road, local street etc. Link gradients across the model domain were calculated using LIDAR DTM datasets.

A map showing the locations where canyon effects were modelled is presented in Figure 9.

Figure 9: Location of street canyons modelled



4.3 Road traffic modelling

4.3.1 Average daily vehicle flow and speeds

Baseline and future year annual average daily traffic (AADT) link flows for each model link will be provided by SYSTRA using outputs from the Sub-Regional Transport Model (SRTM) that covers the areas of Southampton, Portsmouth and South Hampshire.

Baseline daily average link speeds were calculated using the DfT Traffic Master GPS measured datasets cross referenced with the Ordnance Survey ITN roads GIS dataset. This will provide observed average speed data over defined road links at a fairly well resolved spatial resolution. It should also provide a reasonable representation of the change in emissions at locations where typical vehicle speeds are reduced e.g. approaching junctions. A typical UK week day diurnal profile[20] was assumed and applied as time varying emissions in AERMOD when creating the RapidAir dispersion kernel.

4.3.2 Vehicle fleet composition

Vehicle emission rates for the vehicle categories buses (including coaches), taxis, rigid HGVs, articulated HGVs, LGVs, cars and motorcycles can be calculated using the latest COPERT v5 NOx emission functions.

The traffic model will provide vehicle flows for four highway user classes which are: Car, HGV, LGV and Buses. A further breakdown of the HGV into rigid and articulated categories and an estimate of the proportion of car traffic that are taxis has been conducted using local traffic count data and ANPR data. An assessment of the ANPR data indicated that the rigid/artic split and proportion of taxis across the city was not constant. To account for this two distinct zoning approaches has been used to reflect the key differences:

- *Rigid/artic split* – this has been zoned as the Western approach to the port and the rest of the city. The splits used are as follows:
  - Western approach: 28.5% rigid, 71.5% artic
  - Rest of city: 69.9% rigid, 30.1% artic
- *Taxi split* – this has been zoned as city centre, with 6.3% of car movements as taxis and rest of the city with 2.4% of car movements as taxis.

Emission calculations for each vehicle category will be based on vehicle fuel type and Euro classification. Information on the local fuel type mix and Euro standard distribution has been collected from the ANPR surveys conducted over one week from the 5th to 11th December 2016. An assessment of the ANPR suggested that for light duty vehicles the Euro class distribution was consistent across the monitoring locations, and for the heavy duty vehicles there was greater variation but not clear pattern as was seen for the rigid/artic split data. Based on this a common distribution of fuel types and euro classifications was used across the whole model domain for each vehicle type. The distribution of fuel type and Euro classification from the local data is shown in figures 8 to 13 below compared to the national average data taken from the NAEI.

Modelling coach emissions

When using the EFT or our in-house equivalent road traffic emissions calculator RapidEms; the assumed fraction of coaches in the bus fleet is 28%. This is the coach fraction specified for Urban/rural UK roads (outside London) in the 2013 and 2015 base year NAEI rtp fleet projections[21]. We are however aware that coach movements were not included in the traffic model outputs so all bus movements would be passenger service vehicles. To account for this when calculating bus emissions, we used an identical local euro fleet breakdown for both the bus and coach vehicle categories. This will however mean that emissions from the additional bus/coach AADT not represented in the traffic model have not been included.

[20] DfT (2018) Table TRA0307_2015 Traffic distribution on all roads by time of day and day of the week in Great Britain

[21] NAEI (2014) rtp_fleet_projection_Base2013_v3.0_final -

Figure 10 Car fuel type split

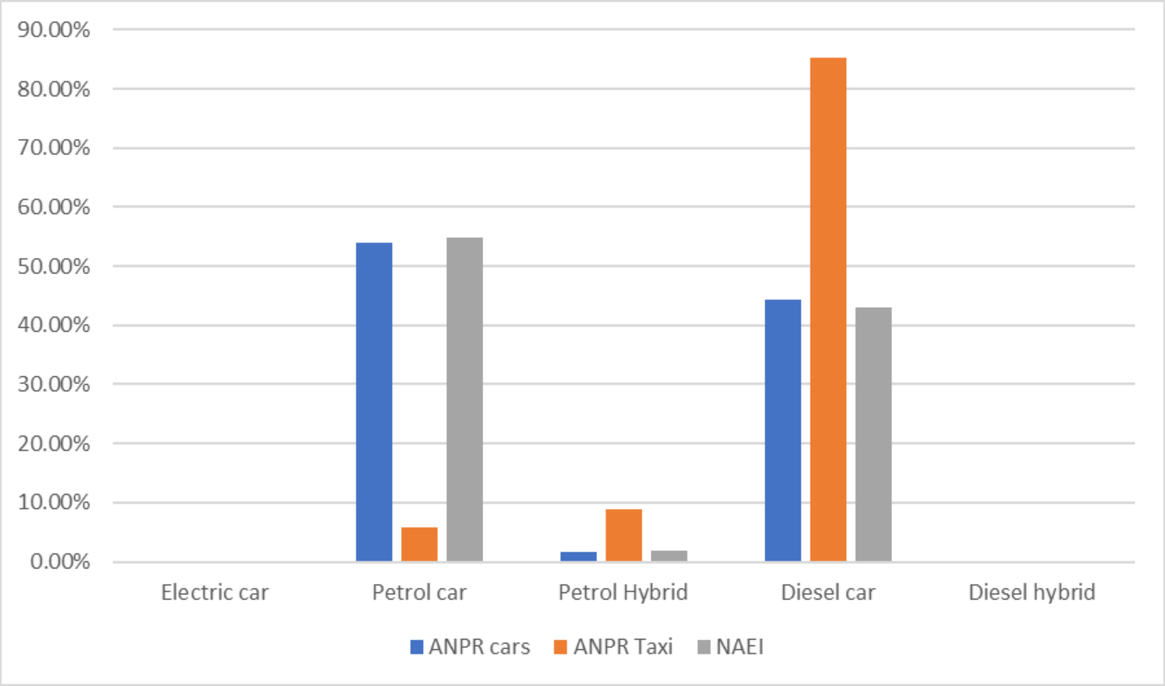


Figure 11 Diesel car Euro classification distribution

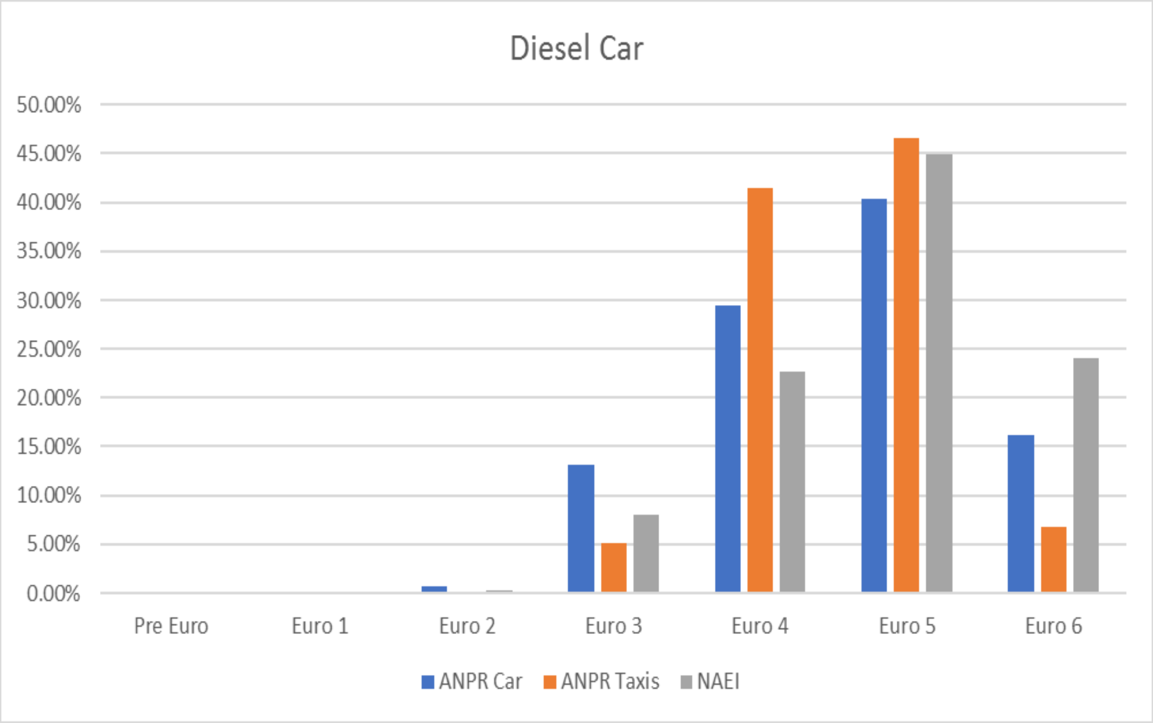
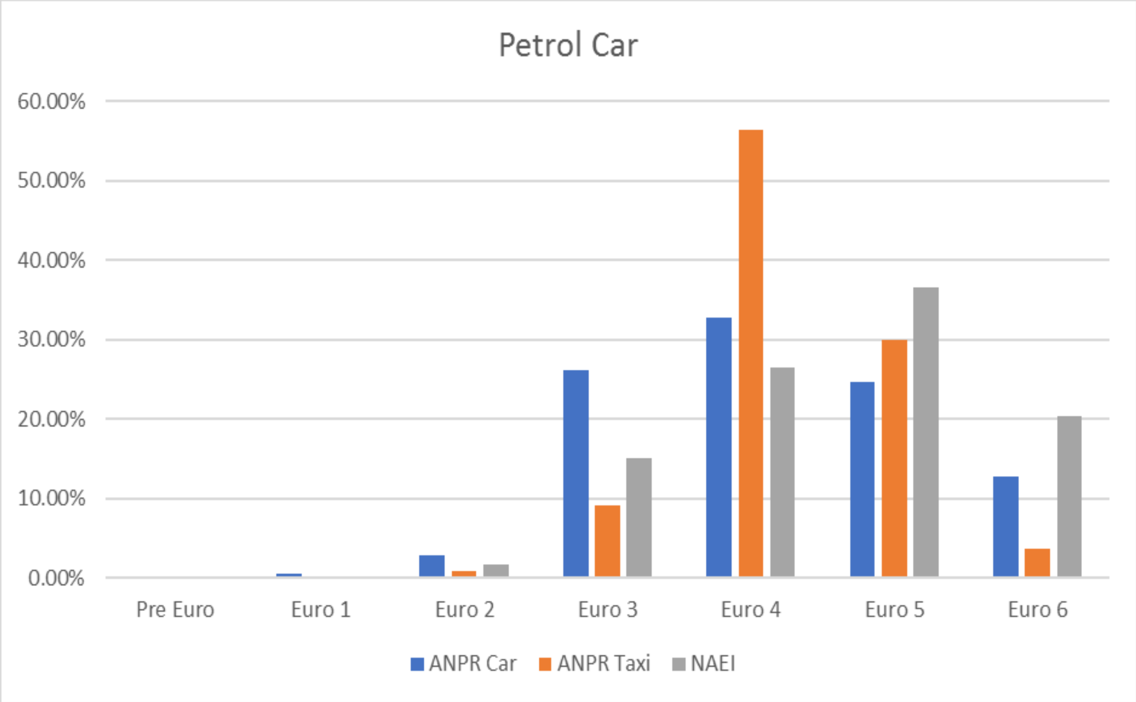


Figure 12 Petrol car Euro classification distribution



The data for cars shows that the fuel type is pretty consistent with the national average, but with taxis having a much higher proportion of diesel as would be expected. The taxis also have a higher proportion of hybrids which is a trend seen in many cities. In relation to Euro classification the local fleet is slightly older than the national average.

Figure 13 Diesel van Euro classification distribution

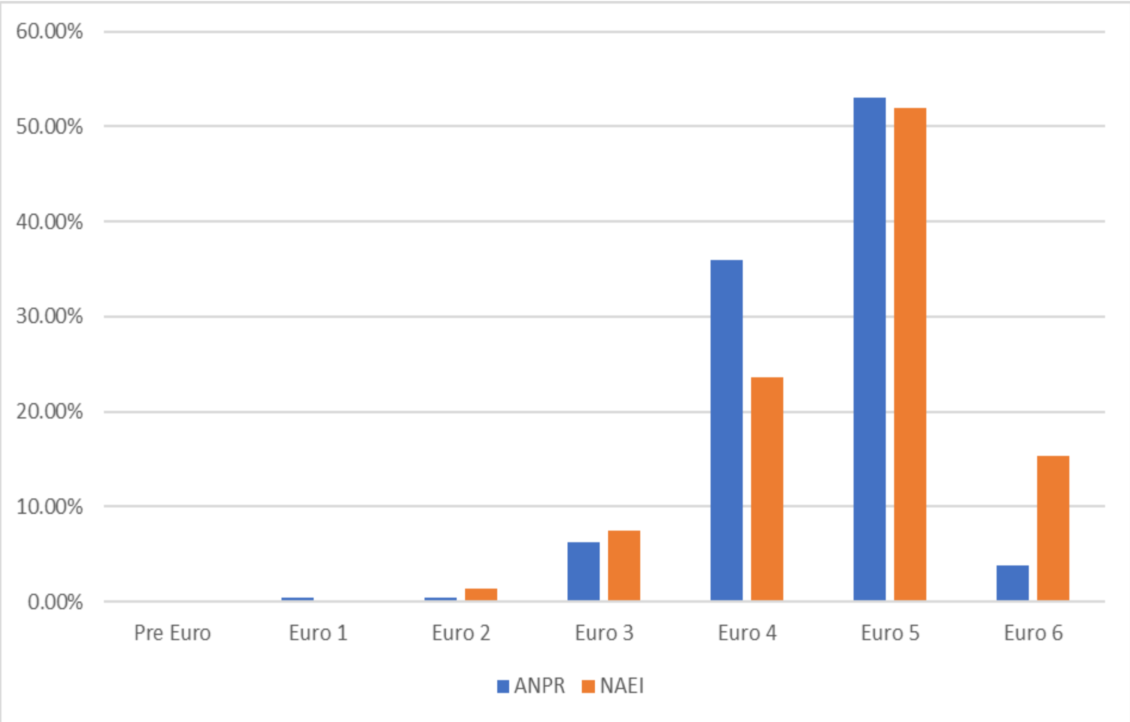


Figure 14 Rigid HGV Euro Classification distribution

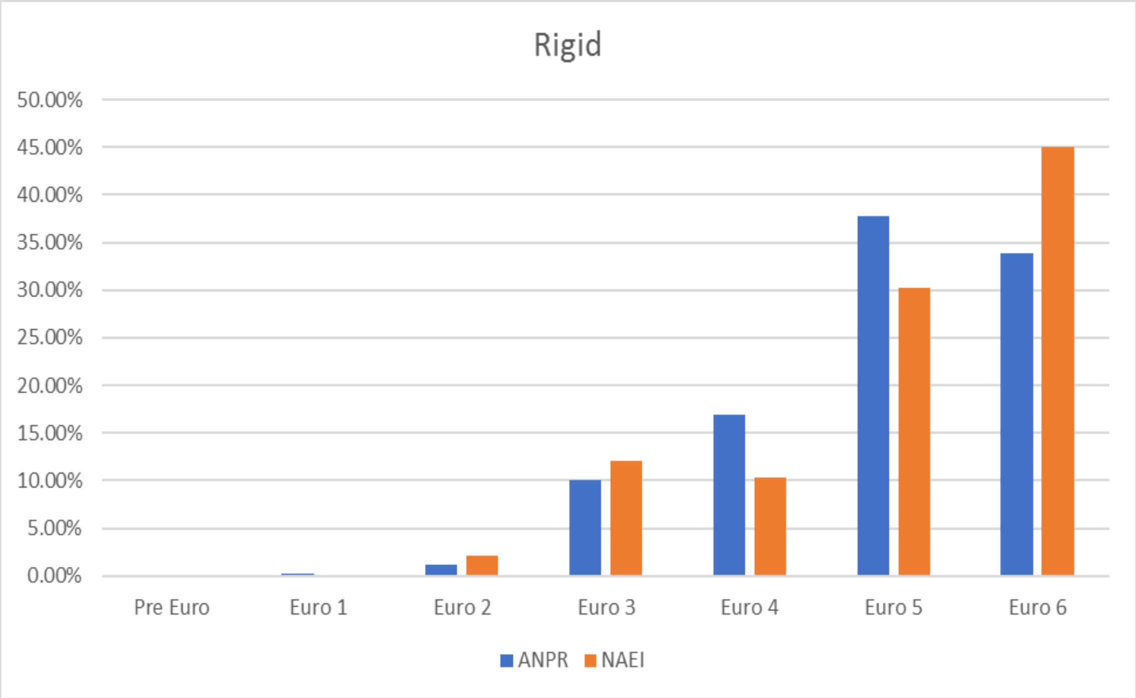
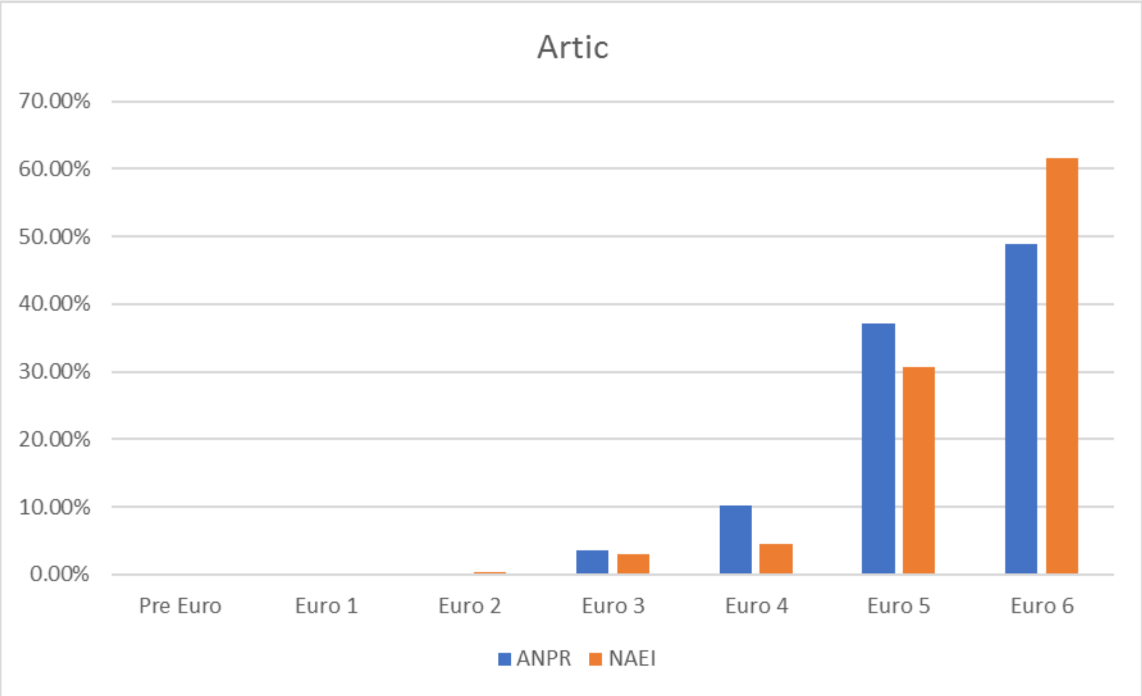


Figure 15 Artic HGV Euro Classification



Like the cars the Euro classification taken from the ANPR data shows a somewhat older van and HGV fleet in Southampton compared to the national data.

Since no additional ANPR data was collected specifically in the New Forest area the fleet composition assumptions will be the same as those in Southampton.

4.3.3 NOx/NO_2 emissions assumptions

Link specific NOx emission factors have been calculated using the COPERT v5 emission functions for all vehicles up to and including Euro 6/VI. Emission rates have been calculated with our in-house emission calculation tool pyCOPERT as agreed by JAQU, which is fully consistent with COPERT v5 and links directly to our RapidAir dispersion modelling system.

JAQU recommend the use of data on primary NO_2 emissions (fNO_2) by vehicle type which is available via the NAEI website (based on 2014 NAEI) to provide a more detailed breakdown than the LAQM NOx to NO2 convertor. This suggests a link specific f-NO_2 emissions estimate for use in the NO_2 modelling.

Based on this requirement, the pyCOPERT road emissions calculation tool now includes additional functionality to calculate fNO_2 emission rates for each road link. Link specific fNO_2 fractions can then be calculated for each link by dividing fNO_2 by total road NOx emission rate.

Calculating link specific fNO_2 emission rates also facilitates dispersion modelling of both road NOx and fNO_2 across the entire model domain to produce separate concentration rasters, which can then be combined with background concentrations to calculate NO_2 concentrations in each grid cell.

The recently updated version (v5.3) of the LAQM NO_x to NO_2 conversion spreadsheet has been used to convert road NOx, fNO_2 and background NOx into NO_2 concentrations where results at discrete receptor locations are required. This currently includes all NO_2 monitoring site locations and receptors placed at 4m from the PCM road links.

To model NOx/NO_2 chemistry across the entire model domain. The city wide domain has been modelled at 1m resolution, the modelled concentration grid rasters have approximately 188 million cells. 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 will not be practical because the calculator is limited to a maximum of 64.6K lines in the excel spreadsheet. The guidance note recommends that it may be possible to use the calculator to define statistical relationships between NO_2 concentrations and the input parameters and use these relationships to calculate NO_2.

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

4.4 Non-road transport modelling and background concentrations

We proposed to model non-road transport sources of NO_x emissions using three types of emission (and background concentration) data.

1. **Southampton port related emissions**: these are perhaps the most important non-road transport source, particularly for the Western Approaches AQMA a key area of concern, and covering emissions from vessels whilst travelling to and berthed at the port and emissions from on-shore port operations, including from road vehicles on private port roads not otherwise captured by the public road transport modelling. Further details of our approach to the port related sources are provided in appendix 4.

2. **Large local point sources**: Emissions from two nearby industrial sources categorised as large point sources in the NAEI have been modelled explicitly using the AERMOD dispersion model at 10m grid resolution. Modelling these sources explicitly aims to provide a more resolved footprint of each sources' contributions to background NOx/NO_2 concentrations than are available from the 1km LAQM background maps. The point sources modelled were:

- Marchwood Power Station
- Marchwood Incinerator

The stack parameters for these large point sources as modelled for the PCM were provided by Defra. Emission rates were calculated using 2015 data from the large combustion plant (LCP) inventory[22]. In the absence of site specific, or published European data on temporal emission profiles, typical operating profiles and weighting factor files as found on the USEPA Clearinghouse for Inventories and Emissions Factors (CHIEF)[23] website were applied to calculate daily and seasonal time varying profiles in AERMOD.

3. **Rail emissions:** As port rail sources were being modelled, it was also necessary to model the national rail network. The latest available (2013) NAEI annual NOx emissions data for the rail network within the model domain was provided by Defra. Dispersion of rail emissions were modelled using rapid air with a bespoke dispersion kernel at 1m resolution. The kernel was created using a release height and initial vertical dimension of the area plume representative of a typical diesel locomotive.

4. **General background sources:** The 1km resolution LAQM background maps were used to provide estimates of all sources not modelled individually as described above.

Road sector contributions from the 2013 base year maps were adjusted to take into account new COPERT 5 emissions using adjustment factors provided by JAQU. The contribution from all road source sectors that were modelled explicitly were subtracted from the background maps.

To avoid double counting of any explicitly modelled non-road transport sources**;** gridded concentrations modelled at fine resolution were resampled to represent average concentrations from these sources over the equivalent 1km background map resolution. The contribution from each source type could then be discounted from the relevant sector in the background maps.

4.5 Measurement data for model calibration

Southampton City Council's 2015 automatic and diffusion tube annual mean NO_2 measurements from roadside sites were used for model verification. Information on monitoring data QA/QC, diffusion tube bias adjustment factors etc. will be as presented in the Southampton City Council 2016 LAQM Annual Progress Report. This has been complemented by available data for the New Forest model domain.

5 Projected future year scenario modelling

5.1 Road transport future year baseline

Future year baseline scenarios have currently been modelled in the year 2020. The main modelling issues for the future year baseline scenarios are:

- **AADT flows for future baseline years** will be provided from the SYSTRA sub-regional traffic model. Further information on how these traffic flows will be derived and how local growth in traffic will be calculated is presented in 'Transport Modelling Methodology Report'.

[22] European Environment Agency (2017) LCP inventory – available at http://cdr.eionet.europa.eu/Converters/run_conversion?file=gb/eu/lcpes/envwrwsia/LCP__Summary_of_emission_inventory__1.xml&conv=538&source=remote

[23] USEPA(2017) https://www.epa.gov/chief

- **Projected fleet split (vehicle type):** All future year scenarios will have the 4 core vehicle category fleet splits provided from the traffic model in the same breakdown as provided for the 2015 base year. The further split of HGV's into artic and rigid, and for taxis will use the same ratios as derived for the 2015 baseline.
- **Projected fuel type and Euro class distribution:** a local fuel type and Euro class distribution has been projected forward from the local ANPR results to provide Euro class distributions for each of the future modelling years. This project has been carried out in line with the draft methodology provided by JAQU. This has been done by deriving future scaling factors from the national NAEI data, applying these to the local ANPR results and then normalising to 100%. This gives an evolution of the local fleet that is slightly behind the national fleet.
- **Future year scenarios average vehicle speed data:** Average link speeds for all future year scenarios will be calculated by adjusting the observed baseline speed data (Traffic Master) by the ratio of the 2015 baseline vs future baseline journey times calculated by the traffic model
- **Projected vehicle NOx emission rates** will be calculated using the latest COPERT v5 NOx emission functions applied to the projected average flows, fleet and vehicle age composition for each future baseline year being modelled.

5.2 Non-road transport projections

5.2.1 Vessels travelling to and berthed at the port

The updated NAEI shipping emissions inventory described in section 4.4 will also include annual projections from its base year of 2014 to 2035. With agreement from BEIS (the sponsors of the projections work) and Defra these projections will be used for modelling vessel emissions. These projections account for the following four changes over time from the base year:

- Changes in activity levels, with assumptions specific for Southampton (up to approximately 5km from the port), and other standard assumptions for shipping activity outside of this distance. The assumptions specific to Southampton of annual average growth rates for specific vessel categories are taken from the Port of Southampton Master Plan 2016 consultation document section on trade and demand forecasts[24].
- Changes in fuel types of vessels. The impacts of the tighter fuel sulphur limit of 0.1% within the SECA from 2015 is accounted for by assuming that vessel operators that used 1.0% S heavy fuel oil in 2014 comply by switching to marine distillate fuel. This is relevant for NO_X due to the slightly lower NO_X emission factor for marine distillates. No LNG is assumed to be used in vessels until from year 2021 onwards in this baseline projection (and then at a rate of 1/3 of new vessels built from 2021 operating in the North Sea and English Channel from year 2021 are assumed to be LNG).
- Changes in vessel fuel efficiency (with consequent impacts on emissions), of annual improvement in vessel energy efficiency of 1% per year. This accounts for improvements from the Energy Efficiency Design Index, as well as changes over time in vessel capacities.
- Changes in emission factors. In relation to NO_X, this accounts for an annual reduction of 0.68% of NO_X emission factors up to 2020 due to the ongoing fleet turnover and thus increasing proportions of newer vessels meeting IMO NO_X Technical Code Tier II levels. Also for NO_X this accounts from 2021 onwards for the expected NO_X emission control area designation of the North Sea and English Channel which includes Southampton Water. This

[24] http://www.southamptonvts.co.uk/admin/content/files/New%20capital%20projects/Master%20Plan%202016/Master%20Plan%202016%20-%202035%20Consultation%20Document%20Oct%202016.pdf

will have only a very minor influence on NO_X emission levels for the post-implementation model year of 2022.

5.2.2 Port operations

For projecting the business-as-usual changes in emissions from port operations, the emissions from each of the sources separately listed in section 4.4 will be subject to two changes over time, implemented as scaling factors relative to the base year:

- Activity level changes. Similarly, to the vessels projections, the activity level changes will be based on the projected demand changes at the port as set out in the Port of Southampton Master Plan[24]. The emission sources related to containers – e.g. straddle carriers etc. – will be scaled according to the forecast changes in demand. For example, the Master Plan includes two container growth scenarios of 2.5% annual compound growth and 3.5% compound annual growth – for this example we will assume that future straddle carrier activity in 2020 is $(1.03)^4$ times larger than the activity level in 2016. The other emission sources will similarly be scaled with the appropriate commodity type demand forecasts.
- Emission factor changes. We have consulted with DP World and have obtained assumptions to make to reflect their planned fleet turnover of straddle carriers. Aside from straddle carriers (estimated as the largest NOx emission source in the port other than vessels), no other equipment fleet turnover will be accounted. The planned straddle carrier fleet turnover will enable us to account for baseline reductions in the NO_X emission factors that will occur. For the modelling of vehicle emissions on in-port roads that arrive/depart through the dock gates, the same assumptions relating to turnover in the vehicle fleet for in-port roads will be made as for public roads.

5.3 Scheme option modelling projections

Four CAZ options have been modelled in detail as described in section 1.2 above. The scheme options will be modelled in 2020 the target implementation. The core fleet categories used in the modelling will comprise cars, taxis, vans, rigid HGVs, artic HGVs and buses will remain the same as the baseline forecasts. The detailed technology and Euro split for the vehicles will be derived separately for the compliant and non-complaint fleet as follows:

- Compliant fleet this will comprise of:
    - naturally compliant vehicles from the baseline forecast;
    - non-complaint vehicles that upgrade based on the JAQU assumption set out in **Error! Reference source not found.**;
    - for the non-compliant vehicles that upgrade we will also use the JAQU assumption in relation to diesel/petrol split for upgrading vehicles;
    - in addition, all upgraded vehicles will be assumed to match the Euro distribution of those in the naturally complaint fleet.
- Non-compliant vehicles – these will have the fleet Euro distribution of the non-compliant vehicles in the baseline forecast

Following the traffic model run the compliant and non-compliant vehicles will be modelled as two separate fleets in the emission model with their own Euro standard distribution. The emissions from each of these fleets will then be added up for each link to give link specific emissions representing the mix of compliant and non-complaint vehicles on that link. Working in this way we are able to capture the behavioural response to the CAZ both in terms of how people upgrade their vehicles and any travel behaviour changes on a link specific basis.

The details of the CAZ options being modelled and the primary modelling assumptions are shown below in Table 3

Table 3 Final list of options for assessment

Option	Components	Modelling approach
Option 1 City Wide CAZ B	City Wide CAZ B	City Wide CAZ B in transport model, feed into AQ model
	Bus grants	Not modelled explicitly as scheme forces uptake
	Taxi incentives	Not modelled explicitly as scheme forces uptake
Option 1A City Wide HGV charging	City wide CAZ for HGVs only	Using transport modelling for CAZ B but only update HGV fleet
	Bus traffic condition	Assume 100% buses in centre comply, 80% elsewhere comply - accounts for fact that most buses pass centre.
	Taxi incentives	Assume 20% of non-compliant vehicles upgrade, 1/3 of JAQU assumption
Option 2 City centre CAZ A Plus LES HGV	City centre Class A	Use base 2020 transport model results Buses- Assume 100% buses in centre comply, 80% elsewhere comply - accounts for fact that most buses pass centre Taxis - Assume JAQU compliance assumptions in centre (upgrade and VKM reduction), Assume 38% upgrade elsewhere (JAQU upgrade X ratio of city centre/rest of city Tax proportions)
	Bus grants	Not modelled explicitly as scheme forces uptake
	Taxi incentives	Not modelled explicitly as scheme forces uptake
	Freight DSP and consolidation	Assume 5% reduction of HGV and LGV traffic in centre, Assume 2.5% reduction in rest of city (reduced LES assumption, alternative is look at using transport model)
	Freight Eco, Port booking, 24hr	Assume 30% non-compliant HGVs upgrade (1/3 of JAQU assumption)
Option 3 Non-charging CAZ	Bus traffic condition plus grant	Use base 2020 transport model results Assume 100% buses in centre comply, 80% elsewhere comply - accounts for fact that most buses pass centre
	Taxi incentives	Assume 20% of non-compliant vehicles upgrade, 1/3 of JAQU assumption
	Freight DSP and consolidation	Assume 5% reduction of HGV and LGV traffic in centre, Assume 2.5% reduction in rest of city (reduced LES assumption, alternative is look at using transport model)
	Freight Eco, Port booking, 24hr	Assume 30% non-compliant HGVs upgrade (1/3 of JAQU assumption)

All background concentration data will remain the same as in the baseline forecasts.

Appendices

Appendix 1: RapidAir street canyon equations

Appendix 2: Details of port modelling

Appendix 1 - RapidAir street canyon equations

The formulations for both models are described below.

USEPA STREET model

The STREET model assumes that the concentration of pollutants within a street canyon location consist of the urban background concentrations and a concentration from vehicle emissions within the street being modelled. The recommendation by the USEPA is to use the concentration from the model at 3m height as background concentrations at the actual receptor height being modelled. Since the canyons are expected to be well mixed over longer averaging periods it is sensible that we use the RapidAir kernel model to provide boundary conditions to the STREET model. Concentrations on the leeward (CL) and windward (CW) side of the canyon are calculated in this method, using the equations below:

$$CL = \frac{K * Q}{(U + 0.5) * \left[(x^2 + z^2)^{1/2} + L_0\right]}$$

$$CW = \frac{K * Q * (H - z)}{W * (U + 0.5) * H}$$

Where K is an empirical constant (usually set between 10 and 14); Q is the emission rate (g/m/s); U is the wind speed (m/s); L_0 is the length of individual vehicles (set to 3 m in this case); W is the width of the canyon (m); H is the average building height of the canyon (m); x is the distance from emission source to receptor (m); and z is the receptor height.

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 (R^2 = 0.97) perfectly 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 were perpendicular to the direction of the wind. Concentrations 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 RapidAir's implementation of the AEOLIUS model are shown below.

<u>Inputs</u>:

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).

<u>Leeward concentrations</u>:

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}):

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

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) = $u_r\left(\frac{\ln\left(\frac{h_o}{zo}\right)}{\ln\left(\frac{h}{zo}\right)}\right)(1 - d * \sin(\theta))$

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

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

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

<u>Windward concentrations (C_{dwind})</u>:

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

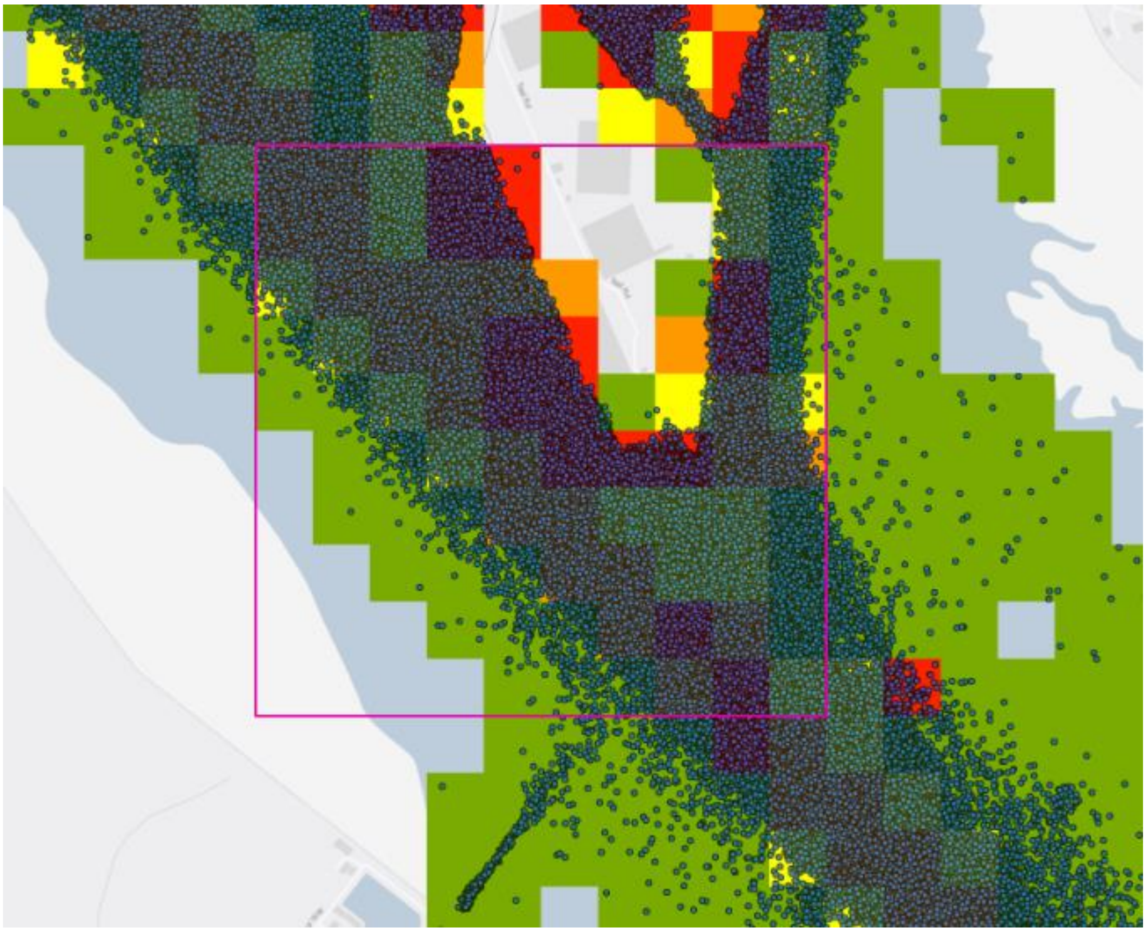
Appendix 2 – Details of port modelling

A2.1 Vessels travelling to, from and berthed at the port

NO_X emissions from vessels travelling to, from and berthed at the port will be taken from the latest estimates in the National Atmospheric Emissions Inventory (NAEI). There is currently an update being made to the estimation of emissions from shipping in the NAEI. Permission has been obtained from the sponsor (the Department for Business, Energy and Industrial Strategy, BEIS) and data provider (the Maritime and Coastguard Agency, MCA) in order to use the latest estimates in advance of their official inclusion into the NAEI.

The updated spatially disaggregated shipping emissions inventory is derived nationally from Automatic Identification System (AIS) data that was provided by the Maritime and Coastguard Agency to Ricardo Energy & Environment. This inventory is for the year 2014, and will be assumed to represent the base year 2015 in terms of quantity and spatial distribution of emissions. The inventory includes annual NO_X emissions per 1km by 1km grid resolution; however, for the purposes of this analysis for Southampton this has been refined to NO_X emissions per 100m by 100m resolution (Figure 16). All vessels that are in scope of the inventory are included, regardless of whether they are undertaking international or domestic voyages.

Figure 16 AIS positions of vessels around the Eastern docks, with purple outline showing 1km resolution, which has been refined to 100m resolution for the purposes of the modelling.



The inventory aims to provide complete coverage of most vessel activity in Southampton Water. It covers all vessels that transmit positions via AIS, with the exception of some vessel types. The vessel types covered and not covered by the updated inventory are shown in Table 4. The emissions from vessel types not included in the updated NAEI shipping inventory (recreational, military) will not be estimated or modelled. However, these are assumed to be negligible compared to the large vessels docking at Southampton port.

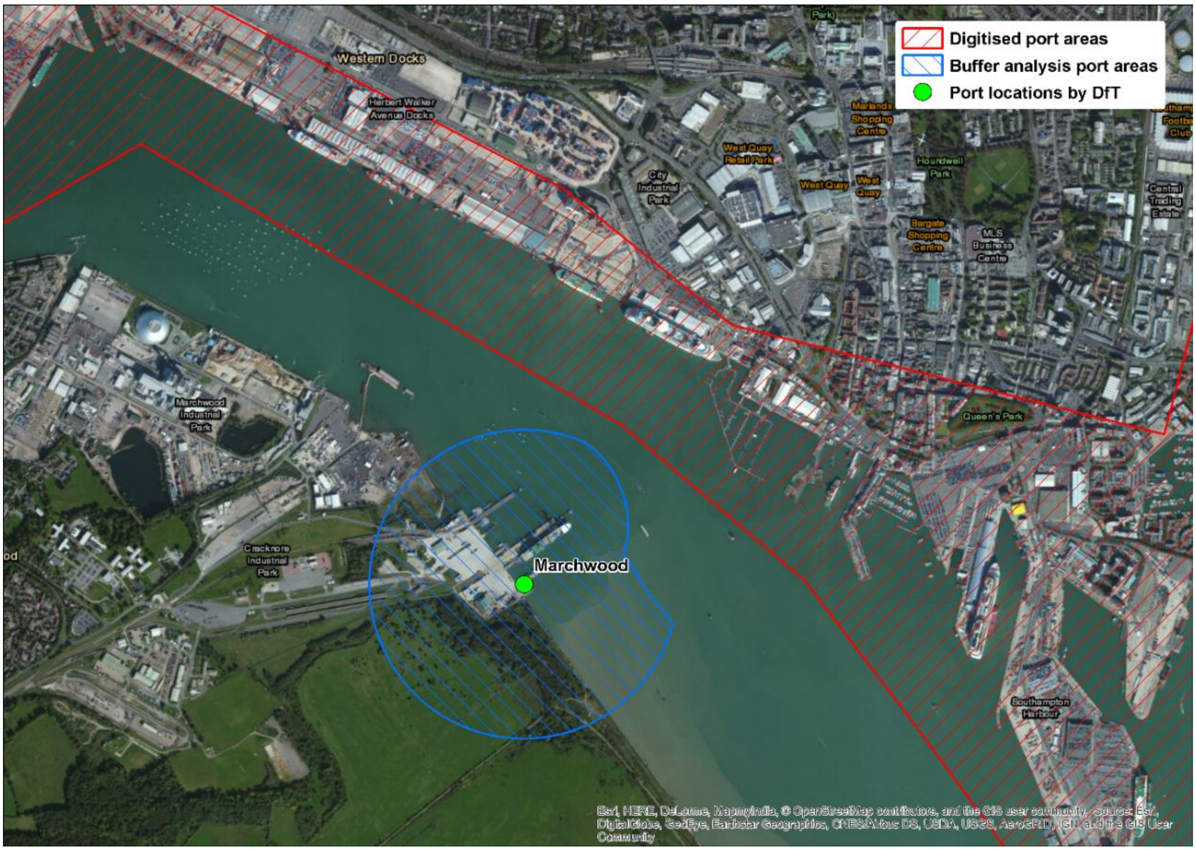
The inventory includes estimates of emissions from vessel main engines as well as their auxiliary engines (generators) and auxiliary boilers if relevant for the vessel type. Cruise ship incinerators are assumed not to be operated whilst in port.

The inventory includes vessels whilst steaming, manoeuvring and whilst at berth. The inventory defines vessels as being at berth when they are reported under AIS as moving at less than 1knot, and when their coordinates are within a port boundary (example shown in Figure 17). The port area for Southampton is considered to be the boundary of the red zone of Figure 17 (zoom only shows western and eastern docks, container terminal not shown but is included). The inventory includes emissions from vessels' auxiliary engines and boilers running whilst the vessel is at berth, capped at a maximum of 24 hours, i.e. if vessels are deemed to be at berth for longer than 24 hours then all their engines are assumed to be off.

Table 4 Vessel types covered and excluded from the updated NAEI shipping emissions inventory

Vessel types included in the spatially disaggregated NAEI inventory		Vessel types excluded from the spatially disaggregated NAEI inventory
• Bulk carrier • Chemical tanker • Container • General cargo • Liquefied gas tanker • Oil tanker • Other liquids tankers • Ferry-pax only • Cruise	• Refrigerated bulk • Ro-Ro • Vehicle • Service - tug • Miscellaneous - fishing • Offshore • Service – other (including e.g. dredgers) • Miscellaneous - other	Recreational vessels – pleasure craft and other inland waterway vessels Military vessels. Noting Marchwood Military Port is on south side of Southampton Water. Any other vessels that did not operate AIS

Figure 17 Sample port boundaries used to define when vessels are at berth



The emission release heights that will be assumed per vessel type are shown in Table 5. These are based on:

- For cruise ships, inspection of planned cruise ship calls at Southampton in 2017, and literature research on vessel heights excluding draught.
- For container ships, inspection of recent container ship calls at Southampton, and weighted average according to vessels over 300m length (assumed funnel height of 57m), vessels 200-300m length (assumed funnel height 39m) and vessels less than 200m (assumed funnel height above water 26m)
- All other merchant vessels assumed 30m based on EC study[25]
- Ferry-pax based on average estimated heights of Red funnel ferries and Hythe ferry
- Other vessel types estimated.

[25] http://ec.europa.eu/environment/enveco/taxation/ship_emissions/pdf/app2final.pdf

Table 5 Assumed vessel emission release heights

Vessel type	Height above waterline (m)
Bulk carrier	30
Chemical tanker	30
Container	44
General cargo	30
Liquefied gas tanker	30
Oil tanker	30
Ferry-pax only	10
Cruise	61
Refrigerated bulk	30
Ro-Ro	30
Service - tug	5
Miscellaneous - fishing	5
Offshore	10
Service - other	5
Miscellaneous – other	5

A2.2 Rail

Emissions from freight and passenger trains operating on the mainline through Southampton City Centre will be taken from the background NAEI maps as the emissions in the NAEI for rail freight have been spatially disaggregated across the core rail network which includes the main line at Southampton.

The NAEI base maps of emissions from rail will be used. However, rather than including these at the 1km resolution, they will be refined to instead represent the emissions as line sources along the Network Rail Strategic Route networks, for each of rail freight, intercity and regional.

A2.3 Port operations

The assessment of port operation emission sources needs to identify the main sources of NO_X emissions from the port, and assign them as point, line (mobile) or area sources to be modelled. The following emission sources will be estimated:

- Cargo handling equipment:
  - Straddle carriers
  - Freight Trains
  - HGVs-containers
  - Car transporters
  - HGVs – other goods e.g. foodstuffs
- Other service vehicles:
  - Forklifts
  - Any top/side loaders
  - Other port vehicles
- Emissions from vehicles driven off (import) and driven on (export) to RoRo vessels
- Employee and visitor (e.g. cruise customer) private vehicles
- On site power generation (combustion plant) e.g. engines

Shore-side and rail freight container terminal gantry cranes are 100% electric powered and do not need to be included in the port inventory. No on-site power plants or

Straddle carriers

NO_X emissions from straddle carriers will be taken from real-world estimates in a Ricardo study for DP World which measured NO_X and NO2 emissions for six types of non-road mobile machinery (NRMM) straddle carrier diesel engines in use at the port of Southampton. From these measurements it generated total annual emission estimates for the fleet, accounting for each emission standard of straddle carrier. This work already has a complete inventory of straddle carriers.

The straddle carriers will be modelled as two area sources, one area for the 4-high straddle carriers (assumed emission release height 15 metres) which operate landside only (not shipside, nor to the freightliner terminal), and one area for the 3-high carriers (assumed emission release height 12 metres) which also operate shipside and to the freightliner terminal.

Freight Trains

The emissions associated with freight train operation when departing from the mainline and whilst idling during loading/unloading will be specifically modelled as line sources, and will be additional to the rail emissions in the NAEI which do not account for specific rail terminal operation.

The emissions from the freight trains (container, vehicle and gypsum) servicing each terminal will be estimated. Activity rates per terminal (number of train services per week) have been obtained through consultation with a rail freight operator (Deutsche Bahn) at the port, and are shown in Table 6. All activity is assumed to be carried out by line haul locomotives without additional shunting locomotives.

The fuel consumption rates in litres/hour for both idling and for arrival/departure from the port have been identified from engineers in a rail freight operator (9.1kg/hr whilst idling, and 38.6kg/hr during arrival/departure from the port). NO_X emissions will be estimated from the fuel consumption using the NO_X emission factor taken from the existing NAEI (105.5kg NOx/ tonne of fuel). Estimates of the time taken for travel into and out of the port from the mainline have been agreed through consultation with a rail freight operator. The extent of the class 66 locomotives deploying start-stop technology (to turn engines off whilst idling) will also be taken into account.

The activity will be assumed to be spread equally through the year. The emission source will be modelled as a line source, assumed to be emitted at 4m height above land. The specific sources to be considered are summarised in Table 6:

Table 6 Summary of Southampton port rail services. The maritime terminal is assumed to be used in preference to the Millbrook terminal.

Cargo	Location	Operator	Number of services	Idling time / service	Duration of travel from and return to mainline
Cars	Eastern docks (Figure 18)	Deutsche Bahn	25-30/week, 46 weeks/year	1.25 hours*	0.5 hours
Vans	Western docks Ro-Ro terminal (19)	Deutsche Bahn	3/week, 46 weeks/year	1.25 hours*	0.5 hours
Gypsum	Bulk terminal, Herbert Walker Avenue (19)	GB Rail Freight	2/week, 46 weeks/year	1.25 hours	0.5 hours
Containers	Maritime terminal (Figure 20)	Freightliner	60/week, 50 weeks/year	1.25 hours	0.25 hours

Containers	Rail terminal, Herbert Walker Avenue (19)	Deutsche Bahn	26/week, 50 weeks/year	1.25 hours*	0.5 hours

** 90% of idling time is with engines off, due to stop-start technology retrofitted to Deutsche Bahn Class 66 locomotives*

Figure 18 Location of terminal in Eastern docks. Emissions estimated from departure from mainline, shown by red line

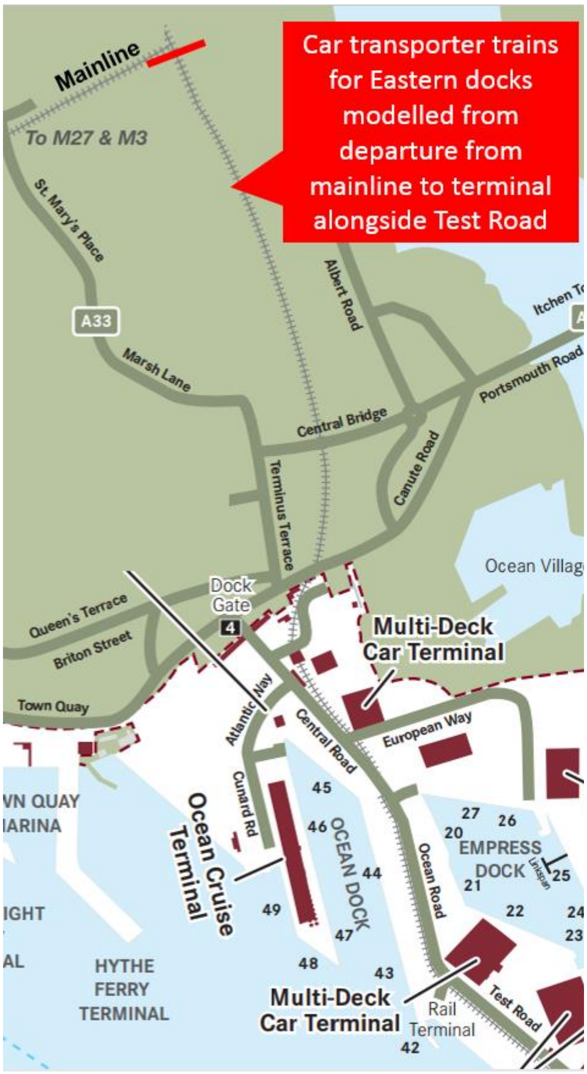


Figure 19 Location of terminal at Herbert Walker Avenue. Emissions estimated from departure from mainline, shown by red line

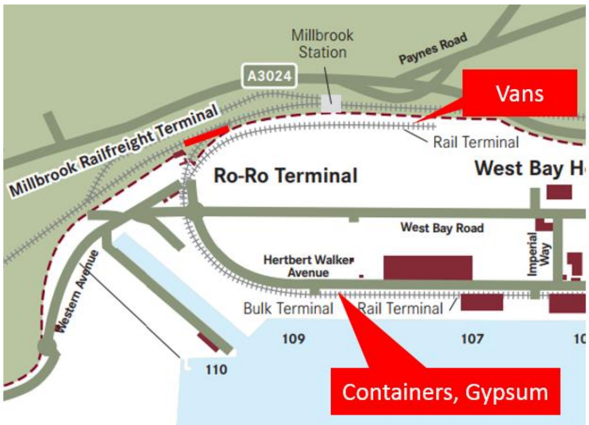


Figure 20 Location of freightliner terminal. Emissions estimated from departure from mainline, shown by red lines

No assessment will be made of the railway network running to the Marchwood military port on the south side of the River Test estuary.

Vehicles operating within the port having entered from public roads

NO_X emissions from vehicles that operate within the port having entered to the dock via dock gates will be modelled as an extension of the road traffic modelling. The modelling includes motorbikes, cars (and taxis), light goods vehicles, heavy goods vehicles (including containers and car/van transporters) and coaches. The same fleet (Euro standard) mix of vehicles as are assumed in the road traffic modelling to operate on nearby public roads will be adopted.

Annual average daily flows per road link will be estimated from:

- Count data per vehicle type from a fortnight in 2015 from SCC, multiplied up to represent one year (Table 7)
- Assumptions related to which road links within the port each vehicle type will travel on depending on the dock gate entered (Table 9).

This assumes no idling during unloading/loading. The resulting estimated annual vehicle flow rates are shown in Table 8.

Table 7 Number of journeys via each dock gate per vehicle type in 2015 (estimated from 2 weeks of SCC count data from summer 2015

Entry/exit	Motorbike	Car/taxi	LGV	Rigid HGV	Artic HGV	Bus/coach
Dock gates 4+5	12,168	343,311	139,191	77,467	42,718	4,752
Dock gate 8	1,300	58,773	26,741	5,083	1,313	878
Dock gate 10	11,622	263,673	109,031	52,546	72,852	4,849
Dock gate 20	17,433	285,032	79,313	182,806	234,338	2,015

Table 8 Flows assumed per year per road link, excluding exclusively in-port vehicles

Road link	Motor-bike	Car	LGV	Rigid HGV	Artic HGV	Coach / Bus
Central road N of roundabout	12,168	343,311	139,191	77,467	42,718	4,752
Central road S of roundabout to junction with European Way	6,692	188,821	92,794	51,645	35,598	2,376
Central road from junction with European Way to Ocean Road	5,476	154,490	46,397	25,822	21,359	2,376
Old road	0	0	0	0	7,120	0
Atlantic way	12,168	343,311	139,191	77,467	42,718	4,752
Cunard road	10,951	308,979	46,397	25,822	0	2,376
Ocean road	5,476	154,490	46,397	25,822	21,359	2,376
Test road	5,476	154,490	46,397	25,822	21,359	2,376
European Way	1,217	34,331	46,397	25,822	14,239	0
Eastern end of Herbert Walker Avenue to T junction with Solent Road	1,300	58,773	26,741	5,083	1,313	878

Road link	Motor-bike	Car	LGV	Rigid HGV	Artic HGV	Coach / Bus
Solent road (between roundabout and T junction)	0	0	13,371	2,542	657	0
Southern road	11,622	263,673	109,031	52,546	72,852	4,849
Eastern end of Herbert Walker Avenue to T junction with Solent Road	3,874	87,891	0	0	0	0
Solent road (between roundabout and T junction)	3,874	87,891	54,516	26,273	36,426	4,849
Herbert Walker Avenue between Solent road and Imperial Way	3,874	87,891	54,516	26,273	36,426	4,849
Herbert Walker Avenue between Imperial Way and roundabout meeting West Bay road	0	0	54,516	26,273	36,426	0
West Bay road east of junction with Imperial Way	7,748	175,782	109,031	52,546	72,852	4,849
West Bay road west of junction with Imperial Way	0	0	54,516	26,273	36,426	0
Imperial way	7,748	175,782	109,031	52,546	72,852	4,849
First avenue from A33 to roundabout	17,433	285,032	79,313	182,806	234,338	2,015
Western avenue west of roundabout junction with First Avenue	8,717	142,516	0	0	140,603	0
Western avenue east of roundabout junction with First Avenue to roundabout with T3	8,717	142,516	79,313	182,806	234,338	2,015
Western avenue east of roundabout with T3 until roundabout with West Bay Road	8,717	142,516	79,313	182,806	23,434	2,015
West Bay road east of junction with Imperial Way	8,717	142,516	0	0	0	0
Herbert Walker Avenue between Imperial Way and roundabout meeting West Bay road	0	0	79,313	182,806	23,434	2,015

Table 9 Assumptions for traffic routes within the port.

<table>
<tr><th>Dock Gate</th><th>Road link</th><th>Comments-car and motorbike</th><th>Comments-Artic HGV</th><th>Comments rigid HGV and LGV</th><th>Comments buses and coaches</th></tr>
<tr><td rowspan="9">Dock Gates 4+5</td><td>Central road N of roundabout</td><td rowspan="9">Assume that 10% of car traffic that enters at dock gate 4 is to the campus, and 90% for the cruise, which is then 50:50 split of car traffic between two cruise termini. Doesn't cover parking areas.</td><td rowspan="9">Assume all artic HGV traffic is car transporters, split 50% along ocean road (3 of 6 multi decks are here), 33% European way (2 multidecks) and 17% to old road (1 multideck).</td><td rowspan="9">Assumed rigid HGV traffic is equally split along Cunard, Ocean and European Way</td><td rowspan="9">Assume half service QEII terminal and half service the Ocean cruise terminal</td></tr>
<tr><td>Central road S of roundabout to junction with European Way</td></tr>
<tr><td>Central road from junction with European Way to Ocean Road</td></tr>
<tr><td>Old road</td></tr>
<tr><td>Atlantic way</td></tr>
<tr><td>Cunard road</td></tr>
<tr><td>Ocean road</td></tr>
<tr><td>Test road</td></tr>
<tr><td>European Way</td></tr>
<tr><td rowspan="2">Dock Gate 8</td><td>Eastern end of Herbert Walker Avenue to T junction with Solent Road</td><td rowspan="2">Assume passengers will only enter dock gate 8 for city cruise terminal</td><td rowspan="2" colspan="2">Assume half go to City Cruise terminal and half to near the Hovis mill</td><td rowspan="2">Assume all go to City Cruise terminal</td></tr>
<tr><td>Solent road (between roundabout and T junction)</td></tr>
<tr><td rowspan="8">Dock Gate 10</td><td>Southern road</td><td rowspan="8">Assume passengers will be 1/3 City Cruise and 2/3 Mayflower cruise terminal. Assume half of Mayflower customers use drop off along quayside.</td><td rowspan="8" colspan="2">Assume half LGV+HGV traffic loops <Southern road-Solent road-Herbert Walker avenue-Imperial way-West Bay Road-Southern Road>, and the other half loop <Southern Road-WestBay Road-Imperial Way-Herbert Walker Avenue-West Bay road-Southern Road></td><td rowspan="8">Assume all loop <Southern road-Solent road-Herbert Walker avenue-Imperial way-West Bay Road-Southern Road></td></tr>
<tr><td>Eastern end of Herbert Walker Avenue to T junction with Solent Road</td></tr>
<tr><td>Solent road (between roundabout and T junction)</td></tr>
<tr><td>Herbert Walker Avenue between Solent road and Imperial Way</td></tr>
<tr><td>Herbert Walker Avenue between Imperial Way and roundabout meeting West Bay road</td></tr>
<tr><td>West Bay road east of junction with Imperial Way</td></tr>
<tr><td>West Bay road west of junction with Imperial Way</td></tr>
<tr><td>Imperial way</td></tr>
<tr><td rowspan="6">Dock Gate 20</td><td>First avenue from A33 to roundabout</td><td rowspan="6">Assume 50% cars and motorbikes entering at dock gate 20 are destined to park in western most car parks, west of Container port, rest travel through to West Bay Road</td><td rowspan="6">Assume 90% of artic-HGV traffic is containers, split equally to T1, T2 and T3. Remaining 10% travels through to Herbert Walker Ave.</td><td rowspan="6">Assume rigid HGVs travel to scrap operator in western docks</td><td rowspan="6">Assume bus/coaches travel to Mayflower cruise terminal</td></tr>
<tr><td>Western avenue west of roundabout junction with First Avenue</td></tr>
<tr><td>Western avenue east of roundabout junction with First Avenue to roundabout with T3</td></tr>
<tr><td>Western avenue east of roundabout with T3 until roundabout with West Bay Road</td></tr>
<tr><td>West Bay road east of junction with Imperial Way</td></tr>
<tr><td>Herbert Walker Avenue between Imperial Way and roundabout meeting West Bay road</td></tr>
</table>

HGV tug/tractor units operating exclusively inside the port

NO_X emissions from HGVs tractor units that deliver containers between the DP World container terminal and the Herbert walker avenue rail freight container terminal will be modelled as a line source along in-port roads – assumed to travel along Western Avenue, West Bay Road east of the junction with Imperial Way, and on Herbert Walker Avenue between Imperial Way and the junction with West Bay road. Data provided by DP World suggested 834 such movements for one week in June 2015. This was assumed to be representative of a typical week, and assuming 51 working weeks per year yielded an estimate of 42,500 movements per year. The emissions for these articulated HGV tractor units will be modelled as part of the road traffic modelling, with the same fleet mix of Euro standards.

This assumes no idling during unloading/loading.

Miscellaneous sources: cranes, NRMM, and vehicles driven on/off RoRo vessels

This category includes stevedoring equipment and vehicles operated and driven within the port and which are not driven outside of the port gates. This emission source will be modelled as two area sources: one area source covering the Eastern Docks and a second covering the Western Docks. For all of the above except vehicles driven on/off RoRO vessels, fuel consumption records or estimates from port operators have been sought. Where fuel consumption records were not identified, fuel consumption was estimated either from other similar equipment inventoried or from fuel consumption factors in the EMEP/EEA air pollutant emission inventory guidebook[26]. NOx emissions are estimated from the annual fuel consumption using NOx emission factors expressed per unit of fuel consumption, selected appropriately to match the equipment in question. It includes the sources listed in Table 10.

Table 10 Stevedoring emission sources accounted for

Operator	Source	Location	Data source
Wallenius Wilhelmsen Logistics (WWL)	Crew buses, forklifts, tractor units	Eastern docks	Fuel records
WWL	Mobile harbour cranes	Eastern docks	Estimated from operating profile
Southampton cargo handling	Various	Eastern docks	Assumed equal to WWL
Williams shipping	Temporary generators, crawler crane and forklift	Eastern docks	Estimated from annual average operational profiles
ABP	Equipment, including CIL harbour cranes. Vehicles including NRMM	Assume split equally Eastern and Western docks	Fuel records
Fruit terminal	Cranes [began operation 2016]	Western docks	Fuel records

[26] https://www.eea.europa.eu/publications/emep-eea-guidebook-2016

S Norton (scrap operations)	Excavators, material handlers	Western docks	Fuel records
Solent stevedoring	Mobile harbour cranes, excavators, bobcats	Assume split equally Eastern and Western docks	Fuel records
Solent stevedoring	Tugs/tractor units, reach stackers	Western docks	Operational profile

The emissions from vehicles which are driven on to and off from Ro-Ro vessels are estimated. The total number of vehicles imported and exported in 2015 was 908,000 as reported in DfT statistics[27] of which the number of "high and heavy" NRMM vehicles imported and exported is around 37,000/yr[28] and it is assumed that the remaining vehicles are 90% cars and 10% vans. The distances travelled to vehicle storage compounds (including multi-decks) in both Eastern and Western Docks are estimated based on the identified locations of Ro-Ro berths and the appropriate vehicle storage facilities. The emission factors will be applied with the EFs from the EEA Guidance for road transport or NRMM as appropriate. All vehicles will be assumed to be of latest applicable euro standard in 2015.

Table 11 Assumptions for estimating NOx emissions from vehicles imported and exported

Vehicle type and storage location	Number imported / exported in 2015	Distance each vehicle driven in port from road/rail transporter to RoRo vessel or from RoRo vessel to road transporter	NOx emission factor
Cars – stored in Eastern docks	621,000	1km	Euro 6. Assumed 50% petrol (average medium, large: 0.06g/km), 50% diesel (any size: 0.5g/km).
Cars – stored in Western docks	162,900	3km	
Vans – Western docks	87,100	3km	Euro 6 diesel (0.5g/km).
NRMM ("high and heavy") – Eastern docks	37,000	0.5km	Fuel consumption assumed to be 5 mpg. NOx emissions factor taken as NRMM Stage V (Tier 2, Agriculture): 1861g/t fuel.
Sources	*DfT, ABP*	*Assumption*	*EEA Guidance 2016[29]*

[27] Port Freight Statistics , Table PORT0211

[28] Personal communication with ABP

[29] https://www.eea.europa.eu/publications/emep-eea-guidebook-2016

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