CLEANER AIR FOR SCOTLAND – NATIONAL MODELLING FRAMEWORK

Low Emission Zone
Dundee Evidence Report

September 2021

Scope of Report

Air Quality modelling for Dundee has been ongoing, supporting the Scottish Government Cleaner Air for Scotland strategy (CAFS). This report follows on from the previous SEPA report 'Dundee LEZ Emissions Report' which focused on calculated tail-pipe emissions of Nitrogen Oxide (NO_x). This work represents the final stages of the National Modelling Framework (NMF), providing modelled NO_2 concentrations to support Dundee City Council's (DCC) proposed Low Emission Zone (LEZ). Traffic modelling has been carried out by SYSTRA to predict changes in vehicle flows and fleet compositions, which was then used to calculate pollutant emissions and air quality concentrations. This report presents the results of air quality modelling work to examine the changes on emissions and concentrations associated with the implementation of the proposed LEZ. Calculated changes in Particulate Matter (PM_{10}) emissions are also presented.

Main Points to Note

- Earlier modelling identified that the highest concentrations of annual-average NO_2 occurred in the City Centre where vehicle emissions were dominated by buses, whilst diesel car emissions dominated other key routes around the city.
- Traffic model outputs indicated relatively low levels of displacement, with the inner ring road experiencing a small increase in car flow, whilst there are general reductions within the LEZ area.
- SEPA's emissions report identified that key bus routes within the LEZ boundary will experience the largest reductions in NO_x emissions by an average of 70%, whilst emissions on Lochee Road will reduce by an average of 20%.
- Air quality model results are based on the age of the Dundee fleet in 2017 and are therefore precautionary, given that further fleet improvements are expected before LEZ implementation.
- Air quality model results indicate that exceedances modelled inside the LEZ for the base year of 2017 would all be removed following LEZ implementation.
- Air quality concentrations increase very locally on Greenmarket, leading from the inner ring road to Greenmarket car park. Concentrations here remain low.

- Localised exceedances may remain on Dock Street, despite a small decrease in NO_2 concentrations due to the LEZ.
- There is a small decrease in NO_2 concentrations along Lochee Road and Logie Street, including at locations where NO_2 exceedances were observed in 2019.
- The LEZ is expected to lead to substantial reductions in tailpipe emissions of PM10, most notably on bus routes inside the LEZ.

List of Abbreviations

AADT	Annual Average Daily Traffic
ADMS	Atmospheric Dispersion Modelling System
ADMS	Urban Atmospheric Dispersion Modelling System for Urban Environments
ANPR	Automatic Number Plate Recognition
AQMA	Air Quality Management Area
ATC	Automatic Traffic Counters
CAFS	Cleaner Air for Scotland
CERC	Cambridge Environmental Research Consultants
DCC	Dundee City Council
DfT	Department for Transport
DEFRA	Department for Environment Food & Rural Affairs
DVLA	Driver and Vehicle Licensing Agency
EFTv8	Emissions Factors Toolkit v8.0
EMIT	CERC Emissions Tool
HGV	Heavy Goods Vehicle
JTC	Junction Turn Counts
LAQM	Local Air Quality Management
LEZ	Low Emission Zone
LGV	Light Goods Vehicle
NAEI	National Atmospheric Emissions Inventory
NLEF	National Low Emission Framework
NMF	National Modelling Framework
PDT	Passive Diffusion Tube
SEPA	Scottish Environment Protection Agency
SG	Scottish Government
TS	Transport Scotland

List of Chemical Abbreviations

NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxides
PM_{10}	Particulate Matter less than 10µm in diameter

Contents

List of Figures

List of Tables

Introduction

Background

As part of the National Modelling Framework (NMF) and National low Emission Framework (NLEF) process within the Cleaner Air for Scotland (CAFS) strategy, an air quality model was built using good quality data and performance validated against air quality monitoring data. The principals and methodology underpinning the model development is set out in the SEPA Aberdeen Pilot Project (SEPA, 2017). A consistent approach to air quality model development has been taken across all four cities implementing Low Emission Zones (LEZs).

Following on from the initial air quality modelling and evidence presented to Dundee City Council and SYSTRA (SYSTRA, 2019b) during the early stages of the LEZ development, the next step was to model LEZ scenarios. As part of this, further traffic surveys were carried out to identify if there are any significant changes in traffic flows and to detect improvements in the fleet composition due to fleet turnover. DCC commissioned SYSTRA consultants to carry out traffic modelling and predict changes to traffic flows in response to the introduction of an LEZ; the traffic model data was used to run the Air Quality models to assess potential changes in pollutant concentrations.

SEPA Cyberattack

On Christmas Eve 2020, SEPA was subject to a serious and complex criminal cyber-attack that significantly impacted our internal systems and our Air Quality modelling capabilities.

As part of our recovery plan, SEPA implemented a phased rollout programme to restore critical services, re-establish critical communication systems to continue providing our priority regulatory, monitoring, flood forecasting and warning services. Our priority regulatory work programme included the delivery of our NMF obligations to assist in the final assessments of the LEZ options for each city.

Due to SEPAs inability to carry out Air Quality modelling, an alternative approach to allow for local authorities to report to committee in Spring 2021 was discussed at the LEZ Leadership Group meeting held on the 3rd of February 2021. The following steps were recommended by Scottish Government and SEPA on a way forward:

- Continuation of traffic modelling to define potential LEZ options or a preferred LEZ option for each city.

- SEPA to carry out emissions analysis on the traffic model outputs using the established NMF methodology, assessing the impact of the LEZ by comparing traffic and emissions between the reference/base case and LEZ options.

- SEPA to continue detailed AQ modelling during the consultation phase over the summer of 2021 to support the local authorities in finalising the preferred LEZ scheme for Ministerial approval.

Since July 2021, SEPA's air modelling capacity has been restored, however the original modelling data for Dundee was not recoverable, therefore this has resulted in a significant delay to work plans, as some modelling parameters had to be regenerated.

National Modelling Framework

Modelling work presented here continues to follow the NMF approach and methods outlined in previous reports (SEPA, 2017) ensuring a consistent approach in air quality modelling. These include:

- The use of ADMS-Urban and EMIT as used in previous NMF work.

- Processing traffic model outputs in the same way that detailed data from traffic data collection surveys was processed earlier in the NMF process.

- Running the air quality models of each city using identical methods and default model settings as used previously.

- Using the same sources of data for input into the model, such as road layout, road width and building heights.

- Using appropriate meteorological and background emission data obtained from a common source.

- Combining traffic data with published emission information to derive consistent emission estimates.

- More accurate emission information, if available, will be applied in a consistent way.

- Ensure that observations and lessons learned from one city are applied in other cities.

- Process, visualise and report on modelling output in a consistent and informative way.

The model continues to be assessed against measurement data to ensure the model is performing well, which includes updating emission calculations based on Automatic Number Plate Recognition (ANPR) data to account for fleet turnover and localised bus fleet data.

It's important to note that some differences in methodology between the cities have arisen due to different approaches in traffic modelling for each city. DCC, along with Aberdeen and Glasgow, commissioned SYSTRA to carry out traffic modelling using Paramics (a microsimulation traffic model), whilst City of Edinburgh Council commissioned Jacobs to carry out traffic modelling using the VISUM model (a strategic traffic model). There are some differences in how the traffic data is processed into Annual Average Daily Traffic (AADT) as required by the air quality modelling. However, from that point the traffic data is treated in the same way when calculating emissions and processing within ADMS.

The ADMS-Urban software has been updated recently. The main difference compared to the previous version is an update to the way ADMS-Urban deals with canyons, which may lead to some differences between ADMS-Urban model versions. However, the new version of ADMS-Urban (version 5) has been used to re-model Dundee.

Modelling Methodology

Scope of Traffic Modelling

The initial Base Model development is detailed in the report *Dundee Greater City Centre Base Paramics Model Development Report* (SYSTRA, 2019a) and the development of the Reference Case model is detailed in the technical note *Dundee Greater City Centre Reference Case Note* (SYSTRA, 2020). The development of each of the LEZ option models, as defined by DCC are outlined in the Technical Note *Dundee Microsimulation Model LEZ Option Testing Note* (SYSTRA, 2021).

The Reference Case Model for Dundee includes infrastructure changes and committed Local Development Plan forecasts to 2023 as identified by DCC. Following discussion with DCC, it was determined that the full waterfront development would not be completed by 2023 although some components of the project and associated vehicle trips on the existing road network were included in the model. The Reference Case model has been built with the expectation that there will be no background traffic growth (SYSTRA, 2020).

The Reference Case Model was used as a basis to develop three core inner ring road LEZ option tests (Figure 1), namely the three all vehicle LEZ options identified through the NLEF high level appraisal (SYSTRA, 2019b):

- LEZ Option 1 - Inner Ring Road area, including all car parks.
- LEZ Option 2 - Inner Ring Road area, excluding Bell Street and West Marketgait NCP car parks.
- LEZ Option 3 - Inner Ring Road area, excluding Bell Street, West Marketgait NCP and Wellgate car parks.

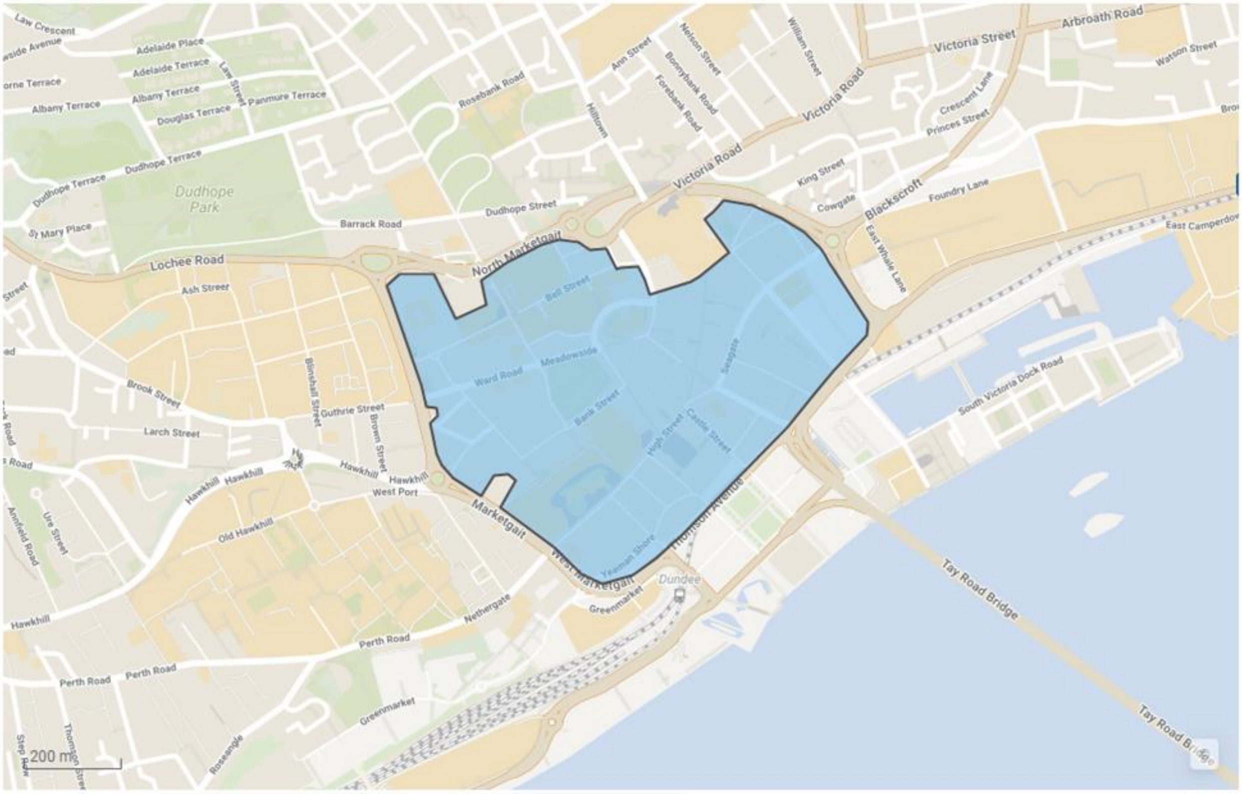

Figure 1: Extent of the LEZ covering the area of Dundee City Centre within the inner ring road.

In addition to these three-core inner ring road options, two further variants were tested where the LEZ was extended along the Lochee Road corridor, as identified through the NLEF public and stakeholder consultation. The Lochee Road option tests were:

- LEZ Option 1/2/3 (above) plus West Marketgait between West Port Roundabout and Dudhope Roundabout and Lochee Road to Tullideph Road.
- LEZ Option 1/2/3 (above) plus West Marketgait between West Port Roundabout and Dudhope Roundabout and Lochee Road to Loon’s Road.

During this LEZ model testing undertaken by SYSTRA, it was identified that the assessment of the Lochee Road corridor options was hindered by network congestion primarily resulting from the inclusion of West Marketgait between West Port Roundabout and Dudhope Roundabout in the LEZ area. It was agreed with DCC that SYSTRA would model further variants of the Lochee Road options, excluding West Marketgait, as follows:

- Lochee Road Variant 1 LEZ Option 1/2/3 (above) plus Lochee Road to Tullideph Road (excluding West Marketgait between West Port Roundabout and Dudhope Roundabout)
- Lochee Road Variant 2 LEZ Option 1/2/3 (above) plus Lochee Road to Loon's Road (excluding West Marketgait between West Port Roundabout and Dudhope Roundabout)

The existing air quality model domain was considered adequate for this piece of work as it covers the city centre in detail, where local displacement of traffic will need to be considered as part of the city centre LEZ. The LEZ rules also needed to be considered when planning this stage of the modelling work, where it is noted that regulations for petrol cars are different from all other vehicles (Table 1). This is because NO_x emissions from petrol vehicles are much lower than diesel vehicles.

Table 1: LEZ rules for Vehicle Categories.

Vehicle category	Compliant	Non-Compliant
Cars (Petrol)	Euro 4, 5, 6	Euro 3 or earlier
All Vehicles (except Cars (Petrol))	Euro 6, Electric	Euro 5 or earlier

Traffic Modelling Methodology

The traffic modelling was carried out by SYSTRA using the Paramics microsimulation model. It is important to note that the traffic modelling carried out for Dundee (along with that carried out for Aberdeen and Glasgow) is a different approach to that used for Edinburgh that utilised the VISUM strategic traffic model. The traffic model was run for 2 scenarios:

1. Reference Case
2. City Centre LEZ

For the Reference Case the traffic model has 7 vehicle types represented; Car, Light Goods Vehicle (LGV), Medium Goods Vehicle (MGV), Heavy Goods Vehicle (HGV), Bus, Coach and Taxi that include both compliant and non-compliant vehicles. The MGV category in the Paramics model is split across the 3 Rigid-HGV classes and the HGV category is split across the 3 Artic-HGV classes.

For the LEZ scenario the 3 vehicle categories; Car, LGV and HGV were further split to provide Compliant and Non-Compliant sub-categories giving 11 vehicle types. Traffic entering, leaving, or travelling within either LEZ is ‘Compliant’. Traffic which is ‘Non-Compliant’ is forced to divert around the LEZ. This may result in ‘Compliant’ traffic taking advantage of quieter roads within the LEZ and changing their route accordingly. Only the displacement of Cars, LGV’s and HGV’s are considered in the LEZ scenarios. It is assumed bus routes will remain unchanged and vehicles will become compliant. Following discussions with DCC and TS it was assumed that all taxis in the LEZ option are compliant (SYSTRA, 2021).

Traffic Flow

Traffic and air quality models must be underpinned by good quality traffic data to ensure traffic flows and the distribution of vehicle types are represented as accurately as possible (SEPA, 2017). Two detailed traffic data surveys were carried out in 2017 and again in 2019 with additional Junction Turn Count (JTC) sites to support the development of the traffic model. In both the Reference Case and LEZ scenario the traffic flows are based on those observed in 2019. Overall, there was a small increase in total traffic flows in the 2019 survey. It was decided that, as the LEZ traffic modelling will focus primarily on Cars, LGVs and HGV’s, and that traffic flows for these vehicles are higher in the 2019 survey, the 2019 traffic data would be used for the LEZ scenarios (Figure 2).

Figure 2: shows traffic flow based on the 2019 survey. Roads are coloured by total traffic flow.

ANPR and Fleet Composition

ANPR survey data provides information linking vehicle number plates to information on the DVLA database such as vehicle type, weight, engine size and fuel type. The DVLA also provide estimated Euro class, based on the age of the vehicle. This information can be processed to derive fleet composition tables, which are required to calculate the emission rates for each road link in the CERC emission database tool, EMIT.

Predicting future fleet composition introduces a level of uncertainty and the National Fleet projections that are published by the DfT are often optimistic. The 2017 traffic data collection survey included the collection of ANPR data, but this wasn't repeated during the 2019 survey. Although ANPR data was collected by Transport Scotland and DCC in 2018, DCC were keen to represent the worst-case scenario regarding displaced traffic volumes and the impacts of these upon emissions so it was agreed that the fleet composition would remain as 2017 for the Reference Case and LEZ scenario (SYSTRA, 2020) (SYSTRA, 2021). It is expected that over time, the fleet will become cleaner as older vehicles are scrapped and new vehicles enter the fleet.

Within the traffic model, Cars, LGV's and HGV's were split into 2 categories, compliant and non-compliant using the values in Table 2. The values are derived from the 2017 ANPR survey:

Table 2: Compliant and Non-compliant percentages used in traffic modelling.

Vehicle Type	Compliance	Fuel Type	Percentage by Vehicle Class
Cars	Compliant	Petrol	51%
		Diesel	17%
	Non-Compliant	Petrol	3%
		Diesel	29%
LGV's	Compliant	Petrol	0%
		Diesel	16%
	Non-Compliant	Petrol	1%
		Diesel	83%
HGV's	Compliant	Petrol	0%
		Diesel	26%
	Non-Compliant	Petrol	0%
		Diesel	74%

In the Reference Case the proportion of bus journeys being made by the lowest-emitting Euro VI buses was 29.4% based on 2017 bus fleet data available in the Dundee Bus Operator tool (Table 3 and Figure 3). An average fleet has been used to represent the entire city, however, it should be noted that there is some fleet variation across the city. In the LEZ scenario the proportion of bus journeys being made by Euro VI buses was increased to 100%.

Table 3: Percentage of Bus Euro Class taken from the Bus Operators fleet and the SEPA Bus Operators Tool (2017).

Bus Class	**Percentage of Bus Fleet**
Euro II	2.0%
Euro III	16.8%
Euro IV	4.6%
Euro V	47.2%
Euro VI	29.4%

The Dundee Bus Operators' tool was used to identify the main bus routes across the city (Figure 3), with a particular emphasis on bus dominated streets within the LEZ boundary.

Figure 3: Main bus routes (shown in red) across Dundee city centre taken from the SEPA Bus Operator tool (pre-Covid 2017).

Each scenario was run over 3 time periods within the traffic model, with the flows for each period summed to provide a 12-hour flow:

- AM: 07:00 – 10:00
- Interpeak: 10:00 -16:00
- PM: 16:00-19:00

The road network in the traffic model consists of approx. 7000 links and is much more detailed than the network in the air quality model consisting of approx. 255 links (Figure 4). Links in the traffic model road network that did not overlap with links in the air quality model road network were removed and the remaining traffic model links were mapped and associated with the appropriate links in the air quality model.

Figure 4: Paramics traffic model road network (grey) and air quality road network (blue).

Calculating Emission Inputs for Air Quality Modelling

The Emission Factor Toolkit version 8 (EfT8) emission factors within the CERC database tool EMIT have been used to calculate emission rates in this analysis which was the most up to date available at the time.

Vehicle categories from the Paramics model were converted into 11-vehicle classes required by EMIT:

- Motorcycle, Car, LGV, Bus/Coach, RHGV-2ax, RHGV-3ax, RHGV-4ax, AHGV-34ax, AHGV-5ax, AHGV-6ax and Taxi.

The goods vehicles were split in line with the proportions identified in the 2017 observed fleet data and counts for buses and coaches were added together. The taxi flows taken from the Paramics model are included in the taxi category in EMIT as black cabs (which assumes emissions are similar to LGV's). This is likely to result in an overestimate in emissions in the Reference Case giving a precautionary approach. In the LEZ scenario all taxis are assumed to be compliant.

To calculate emission rates, 24-hour traffic flows (known as Annual Average Daily Traffic, or AADT) are required, which is not provided by the traffic model. In previous modelling work, traffic flows were calculated using 12-hour and 24-hour JTC data. The junctions that had 24-hour data were already AADT flows. Where data was collected over a 12-hour period, these values were factored up to AADT using conversion factors derived from the 24-hour JTC data, with different factors used for each traffic category.

In this case, new conversion factors had to be derived to convert the traffic model output from 12 hour to AADT and these were derived from Automatic Traffic Count (ATC) data for all road links in the model. Due to the SEPA cyber attack it was not possible to derive these factors from Junction Turn Count (JTC) data as described in the technical report (SEPA, 2017).

Finally, the 2017 fleet composition tables and traffic flow data were used in the CERC EMIT database tool to generate NO_x, NO_2 and PM_{10} emission rates for each road link. These emission rates were analysed to provide information on emission rate changes for each road and were also ready to import into ADMS-Urban to predict NO_x and NO_2 concentrations.

Air Quality Modelling Methodology

The Aberdeen Pilot Project Technical report (SEPA, 2017) outlines the air quality modelling methodology and this remains the same to maintain consistency with previous modelling unless outlined in more detail below, which is mainly focused on the use of traffic model data to examine the effect on introducing an LEZ. The original ADMS air quality model contained approx. 550 road links but this was reduced to 255 links in the revised air quality model (Figure 5).

Figure 5: The revised air quality model network.

The following AQ modelling parameters were used:

- Meteorology: 2017 data from Leuchars Met Office weather station
- Background data: Given uncertainties about the most appropriate source of background data for Dundee, four different methods have been explored. This is discussed in more detail in Appendix 1.
- Traffic Speed: These are based on output from the traffic model. This is discussed in more detail in Appendix 1
- Street Geometry (road widths and canyons): These features were re-calculated from Mastermap using the established NMF methodology (SEPA, 2017).
- 12-hr traffic flows were converted to 24-hr flow using ATC data, due to the unavailability of JTC data.

Results of air quality modelling using Reference case traffic flows were compared against air quality observation, in order to assess the performance of the model. The results of this verification are presented in Appendix 1.

Results

Traffic Model Output

The aim of the traffic model is to predict traffic flow changes in response to the introduction of an LEZ, which is likely to displace non-compliant traffic around the LEZ boundary. The first stage in assessing the effect of these changes on emissions involved processing the Traffic Model outputs to make them compatible with the CERC emissions database tool (EMIT) using conversion factors derived from observed traffic data. Emission rates (g/km/s) were calculated for the vehicle flows along every road in the traffic model for the Reference Case and LEZ scenarios. Comparing emissions between these 2 scenarios enabled any changes due to the LEZ to be identified (SEPA, 2021). Initial findings suggest that implementation of the proposed LEZ will reduce NO_x emissions on key bus routes inside the LEZ boundary by an average of 70% whilst there is an overall reduction of annual NO_x emissions within the LEZ of 78%. The proposed LEZ results in low levels of traffic displacement, except for an increase in car flow on the inner ring road and surrounding car parks, and a small increase in Goods vehicles on the Kingsway. This is linked to very localised increases in NO_x emissions on small sections of road around the edge of the LEZ boundary. These occur on roads that currently have low traffic levels.

The flows along each road in the traffic model used in the emission analysis have been incorporated into the air quality model to predict changes in roadside concentrations due to the LEZ. The absolute differences between Reference and LEZ cases may in some cases be smaller than previously presented in the Dundee LEZ Emissions Report. This is a consequence of aggregating the traffic data, whereby the maximum Reference and LEZ flows from the Paramics model are used in ADMS. The air quality modelling results for the LEZ case still represent a worst-case scenario as these are based on maximum traffic flows.

Predicted changes to road emissions

Inside the LEZ

There is a large reduction in emissions inside the LEZ due to its implementation. In the Reference case there are 8.1 tonnes of NO_x emitted annually, which reduces to 1.8 tonnes of NO_x in the LEZ case. This is due to all vehicles meeting EURO 6/VI standards. Buses remain the largest contributor to NO_x emissions, emitting 0.7 tonnes annually. Diesel cars are the next largest contributor to annual NO_x (0.5 tonnes/year).

In Figure 6, all roads in the model network are ranked by NO_x emission rate (g/km/s) for the Reference case, and in Figure 7 for the LEZ case. In both cases, roads inside the LEZ are highlighted in black, showing the scale of reduction following LEZ implementation. In the LEZ case the roads inside the LEZ have among the lowest emissions rates of this model network.

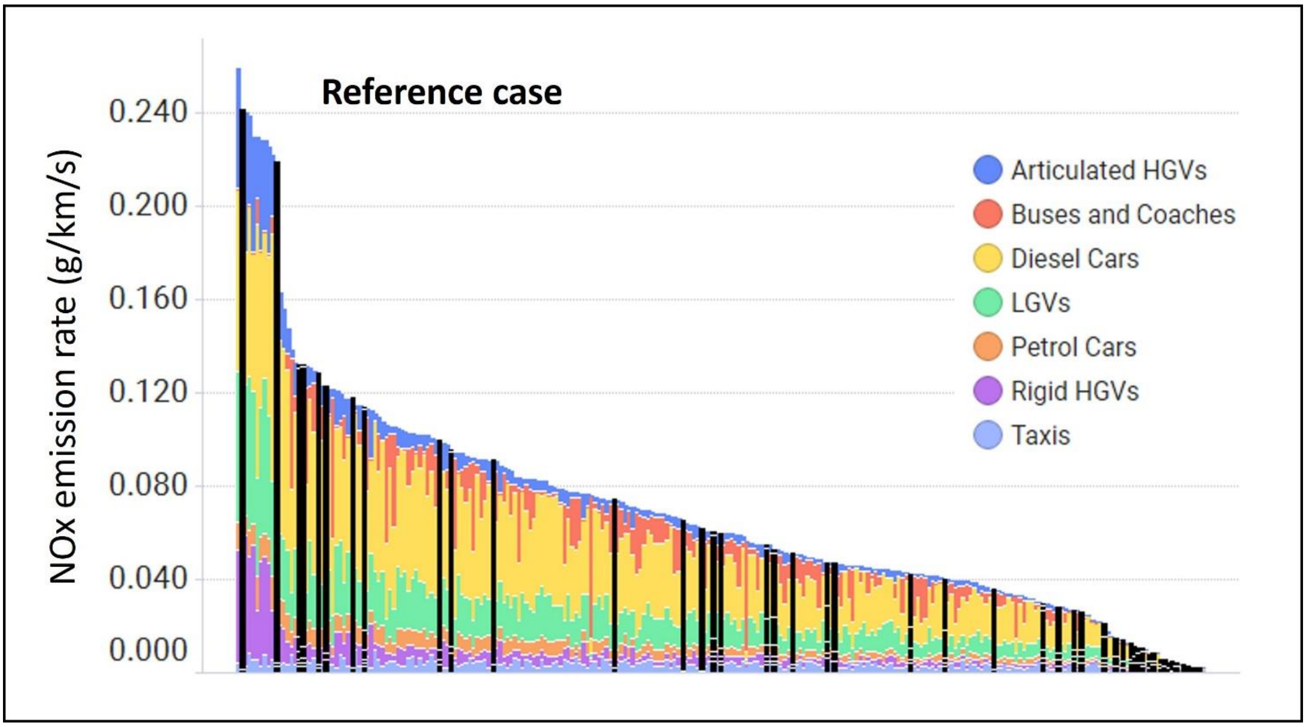

Figure 6: Ranked emissions rates of NO_x (g/km/s) for all roads for the Reference case. Roads inside the LEZ are highlighted in black.

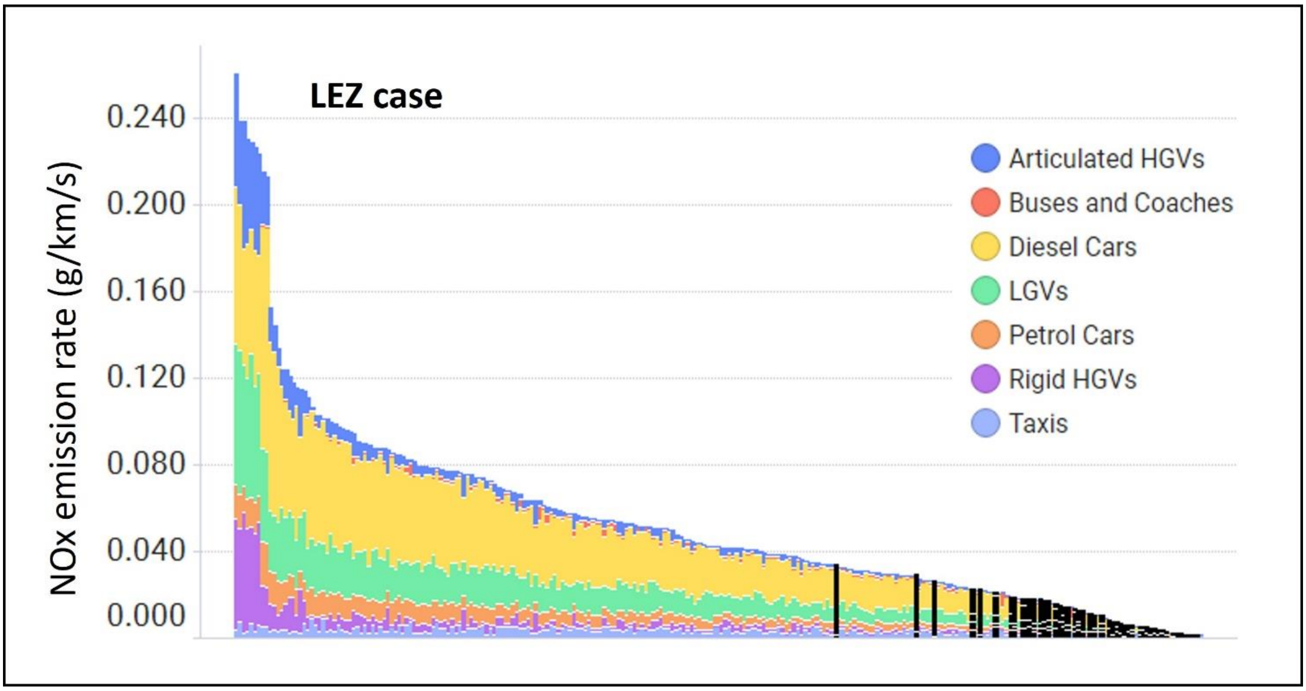

Figure 7: Ranked emissions rates of NO_x (g/km/s) for all roads for the LEZ case. Roads inside the LEZ are highlighted in black.

In addition to cleaner vehicles inside the LEZ there is a small reduction in the number of vehicles entering the zone. In the Reference case there is a maximum traffic flow inside the LEZ of around 6000 vehicles per day. There is a maximum reduction of around 30% to give a daily flow in the LEZ case of around 4000 vehicles per day. This reduction is mainly achieved by fewer cars entering the LEZ.

Emissions inside the LEZ are explored in more detail below by focusing on two sections of road inside the LEZ that are dominated by bus emissions but occupy different positions within the ranking of all emission rates. Seagate is among the highest NOx emitters in the Reference case, while Meadowside is closer to the centre of the distribution. Their locations are shown on Figure 8 and their emissions are shown on Figure 9.

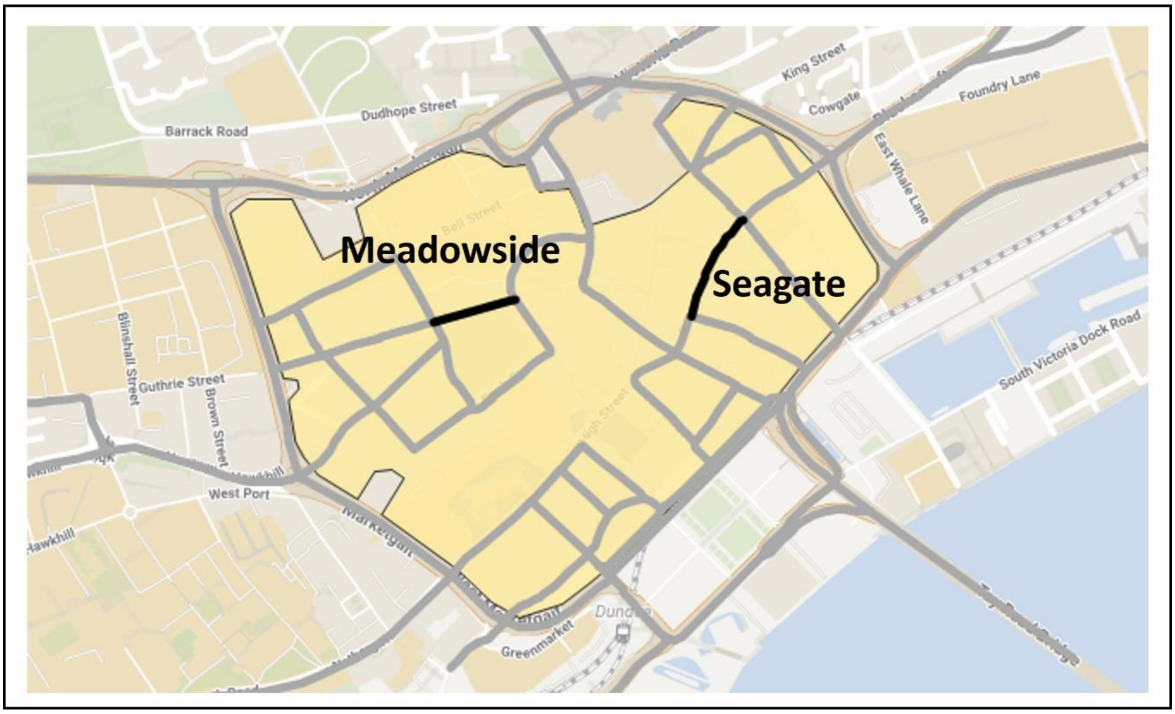

Figure 8: The location of the sections of Meadowside and Seagate examined in more detail below.

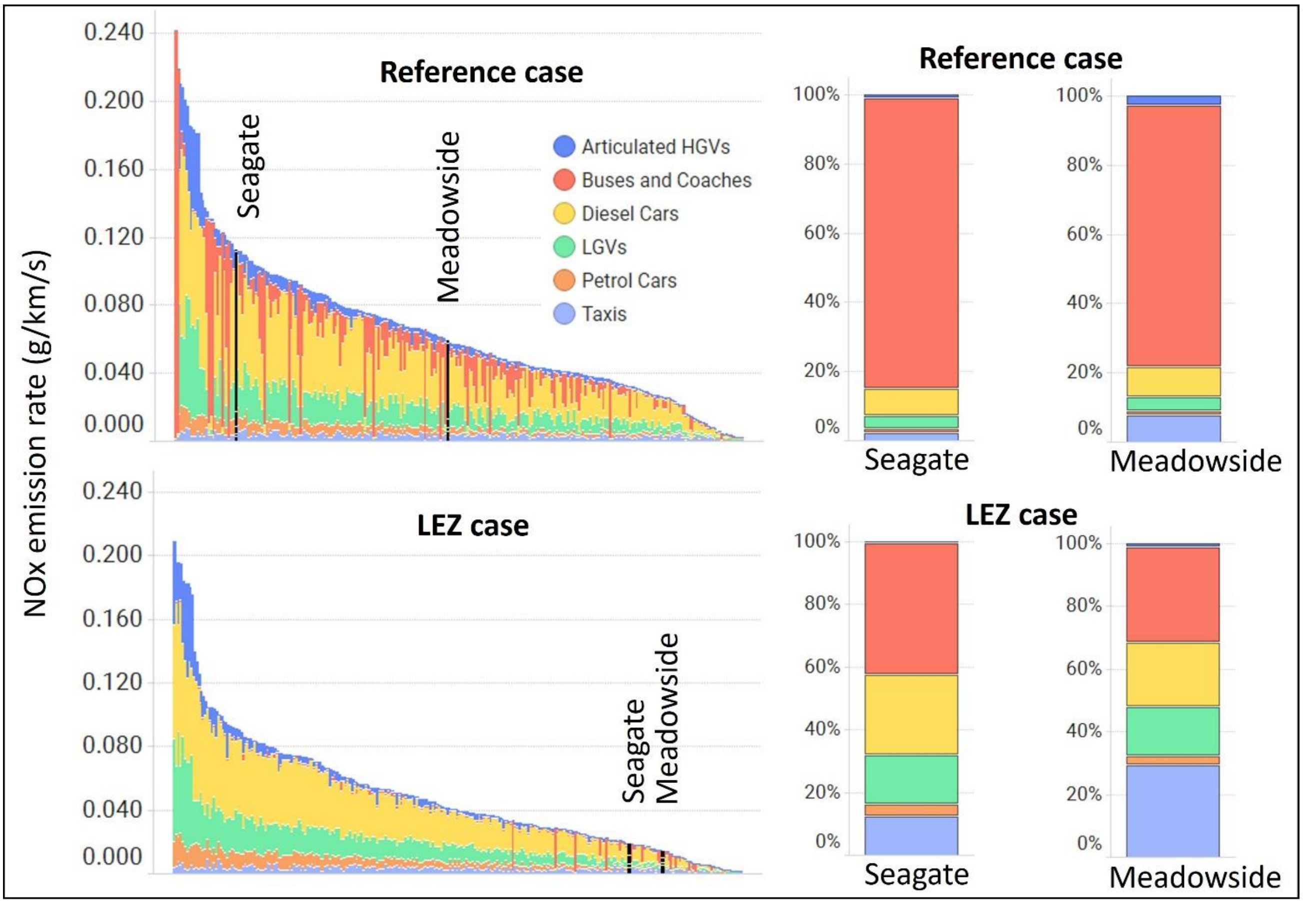

Figure 9: Ranked emissions rates of NO_x (g/km/s) for all roads, with Seagate and Meadowside highlighted in black. Bar charts show the contribution to total NO_x from different vehicle types, for Reference and LEZ cases.

In Figure 9, all roads in the model network are ranked by NO_x emission rate (g/km/s) for the Reference and LEZ cases. Seagate and Meadowside are highlighted in black to demonstrate the scale of reduction in city centre emissions following implementation of the LEZ. This reduction is mainly driven by a cleaner bus fleet with additional reduction from diesel cars.

Inner ring road

Following implementation of the LEZ there is a small increase in the number of vehicles on the inner ring road. On the roads highlighted in black in Figure 10, there are on average around 1000 more vehicles per day, corresponding to an average increase in traffic of less than 10%. Along the section of West Marketgait highlighted on the map there is an increase due to the LEZ of over 2000 vehicles, corresponding to an increase of just under 20%.

Despite a small increase in the number of vehicles on the inner ring road there is a small reduction in total NO_x emissions, due to implementing the LEZ. In the Reference case there are 9.3 tonnes of NO_x emitted annually, compared with 8.5 tonnes of NO_x in the LEZ case. Following implementation of the LEZ just over half of emissions (4.4 tonnes of NO_x) are expected to be from non-compliant vehicles. The section of West Marketgait highlighted on the map experiences a small reduction (~3%) in total NO_x emissions, despite experiencing a larger increase in vehicle numbers.

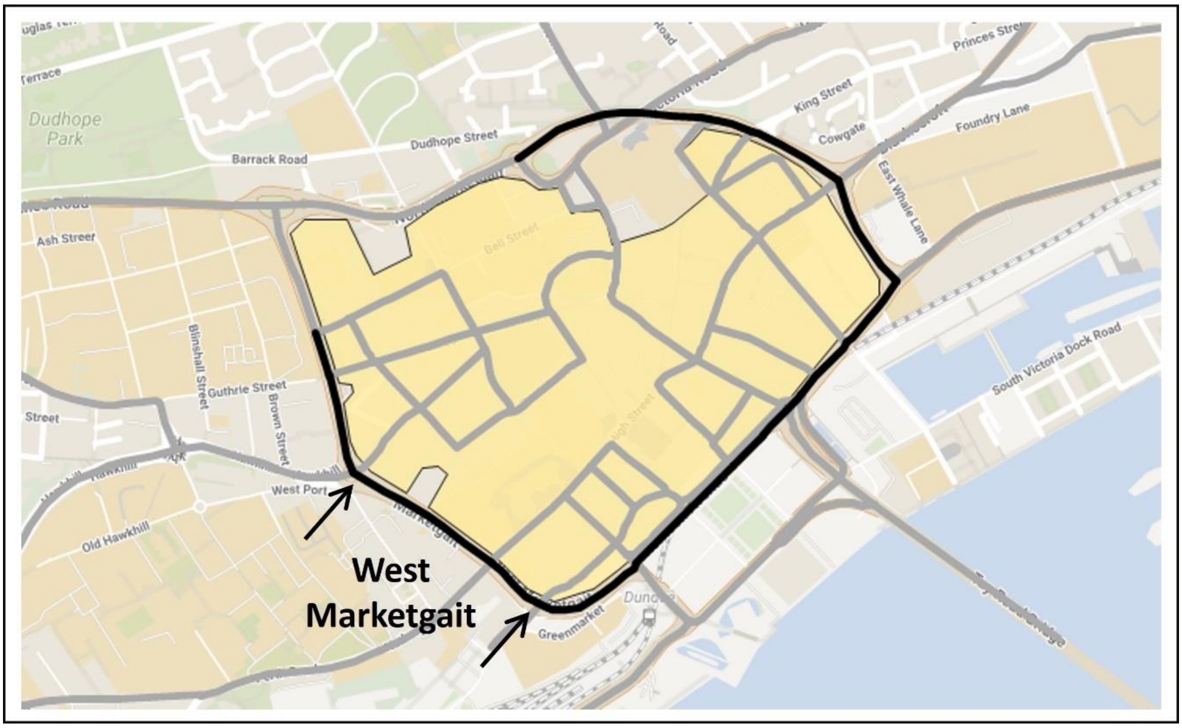

Figure 10: Sections of the inner ring road highlighted in black experience a small increase in traffic volume and a small decrease in NO_X emissions. The section of West Marketgait highlighted is discussed in more detail below.

Source attribution data based on vehicle emissions shows that the contribution from different vehicles does not vary substantially around the inner ring road, with diesel cars the dominant source. On the section of West Marketgait highlighted in Figure 10 the overall reduction in emissions is driven by improvements in the bus fleet due to implementation of the LEZ (Figure 11).

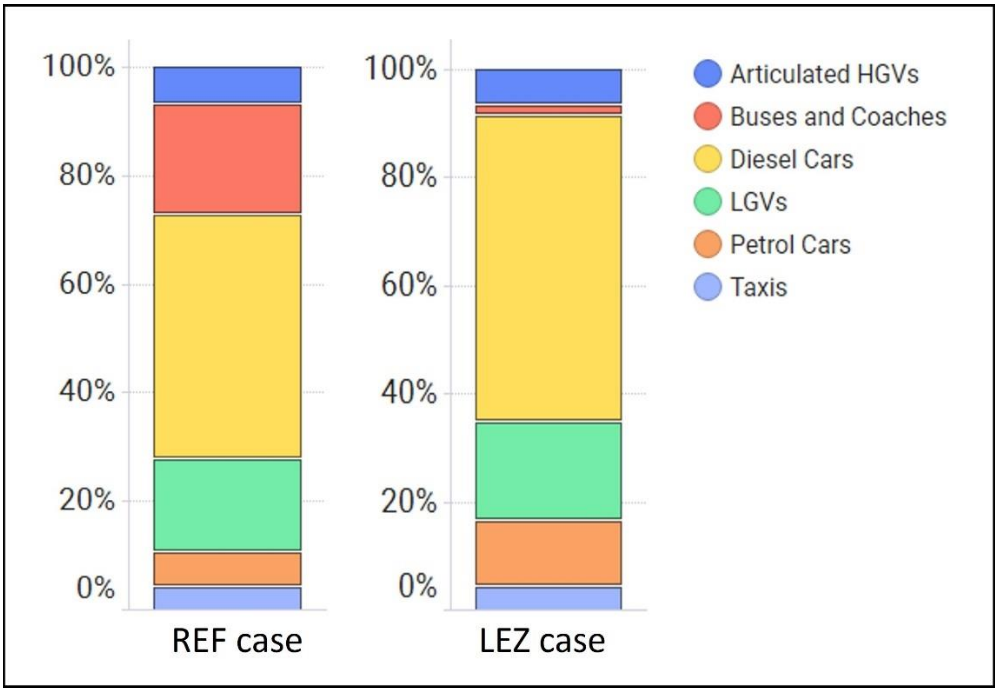

Figure 11: Source attribution of vehicle emissions on a section of West Marketgait on the map.

Greenmarket

The largest percentage increase in traffic due to implementation of the LEZ occurs along Greenmarket, leading from the inner ring road (West Marketgait) to the Greenmarket car park. On this section of road there is an increase of around 60% in the number of cars, corresponding to an additional 1650 cars per day. However, given that the volume of traffic in the Reference case is very low (around 3000 vehicles per day), the emission rate following implementation of the LEZ remains low. This corresponds to low predicted concentrations of NO_2, as discussed in the following section.

In Figure 12, all roads in the model network are ranked by NO_x emission rate (g/km/s) for the LEZ case. Greenmarket is highlighted in black, showing that the emission rate remains low despite a large percentage increase in NO_x emissions.

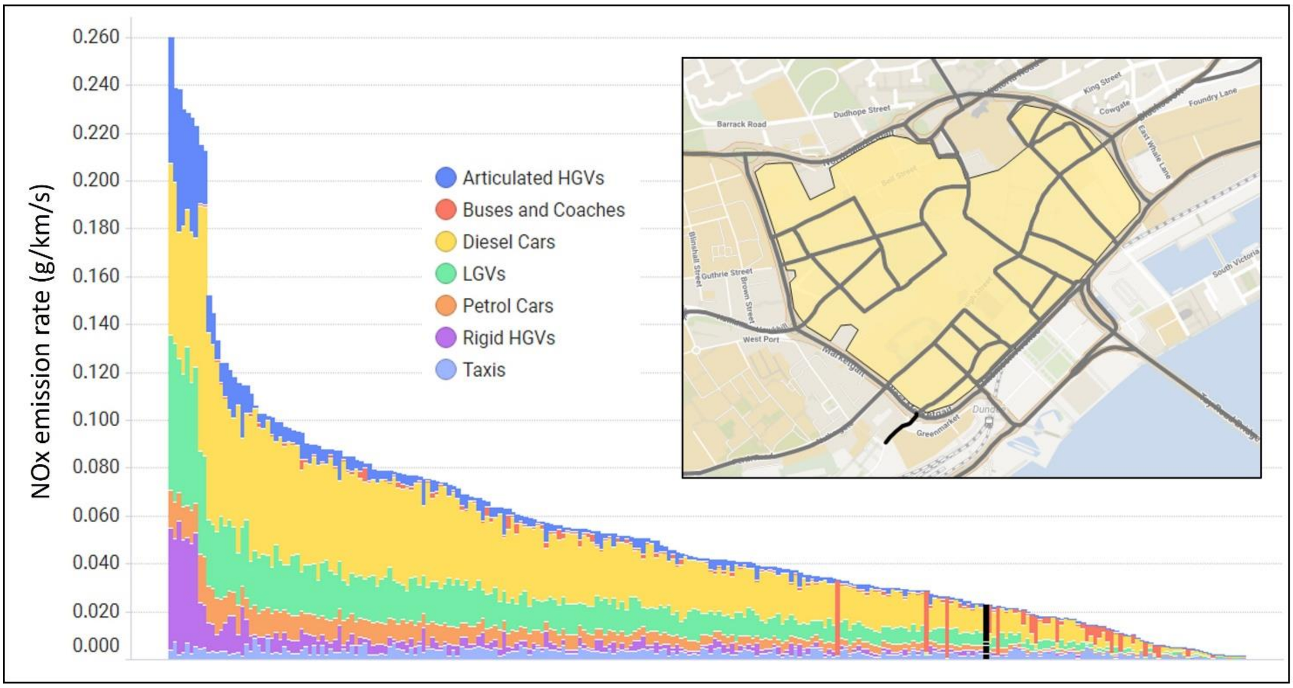

Figure 12: Ranked emissions rates of NO_x (g/km/s) for all roads for the LEZ case, with Greenmarket Road highlighted in black.

Lochee Road

Lochee Road is an area identified as exceeding current AQ standards, with the automatic monitoring station recording an annual mean NO_2 concentration of 43µgm^{-3} in 2019. Passive diffusion tubes in this area have recorded higher concentrations of NO_2, with an annual mean of 46µgm^{-3} on Lochee Road and 47µgm^{-3} on Logie Street, in 2019. When developing the extent of the proposed LEZ, the SYSTRA traffic model was used to explore options that included and excluded Lochee Road (SYSTRA, 2021). Two Variants were tested that included the LEZ extending up Lochee Road. Variant 1 included Lochee Road as far as Tullideph Road, and Variant 2 included Lochee Road as far as Loon's Road (Figure 13).

These options were predicted to cause a significant increase in vehicle numbers on adjacent roads, including City Road. Variant 1 generated a localised impact on the road network, due to the shorter extent of the Lochee Road corridor included within the proposed LEZ. Variant 2 generated greater displacement of non-compliant vehicles over a wider network.

Due to limited capacity of these roads and wider impacts on the Dundee network the Lochee Road variants were not taken forward. The preferred option therefore included only the area inside the inner ring road.

The traffic model data used to help make these decisions can be explored via an online data tool:

https://informatics.sepa.org.uk/dundee-lez-traffic/

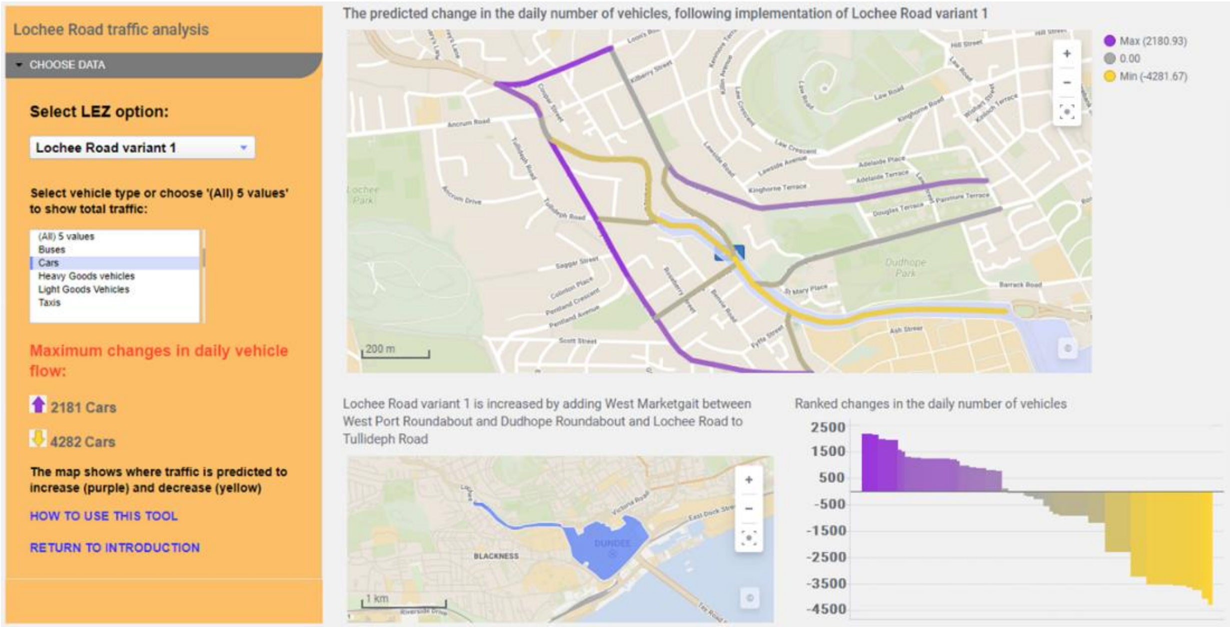

Figure 13: Example from the Lochee Road online data tool, showing predicted traffic displacement of a Lochee Road variant.

The proposed LEZ inside the inner ring road is predicted to cause only small changes in the number of vehicles on Lochee Road, with a total reduction of about 200 vehicles per day. On the section of road highlighted in black in Figure 14 total NO_x vehicle emissions reduce by 19%. On the section of Logie Street located between this and Loon's Road there is a similar reduction in total NO_x emissions of 21%.

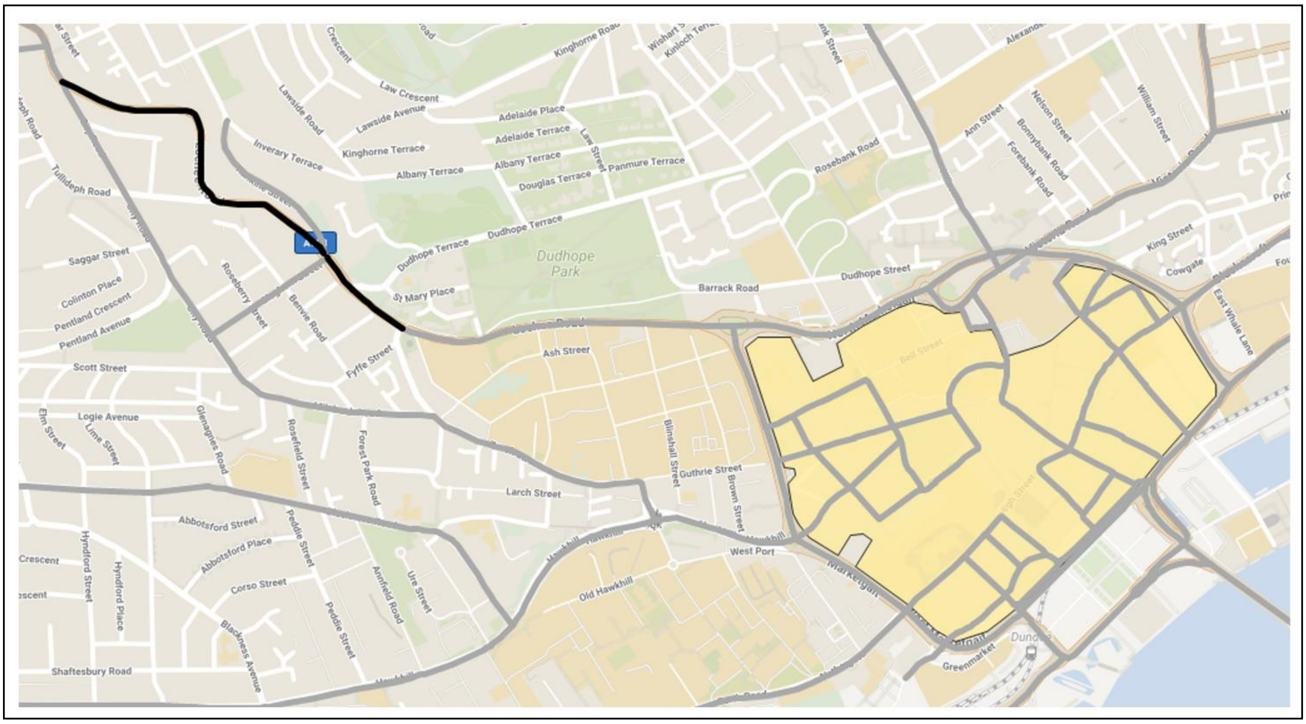

Figure 14: A section of Lochee Road highlighted in black, for which data on changes in traffic and vehicle emissions are presented.

Source attribution data based on vehicle emissions shows that the reduction in emissions on this section of Lochee Road is mainly achieved by a reduction in the contribution from buses (Figure 15). All bus routes using Lochee Road also enter the LEZ and therefore meet the cleanest EURO VI standards. Figure 15 also confirms a small reduction in the emission rates on the sections of road highlighted in Figure 14, with only small changes in their position within the rank of all road emissions.

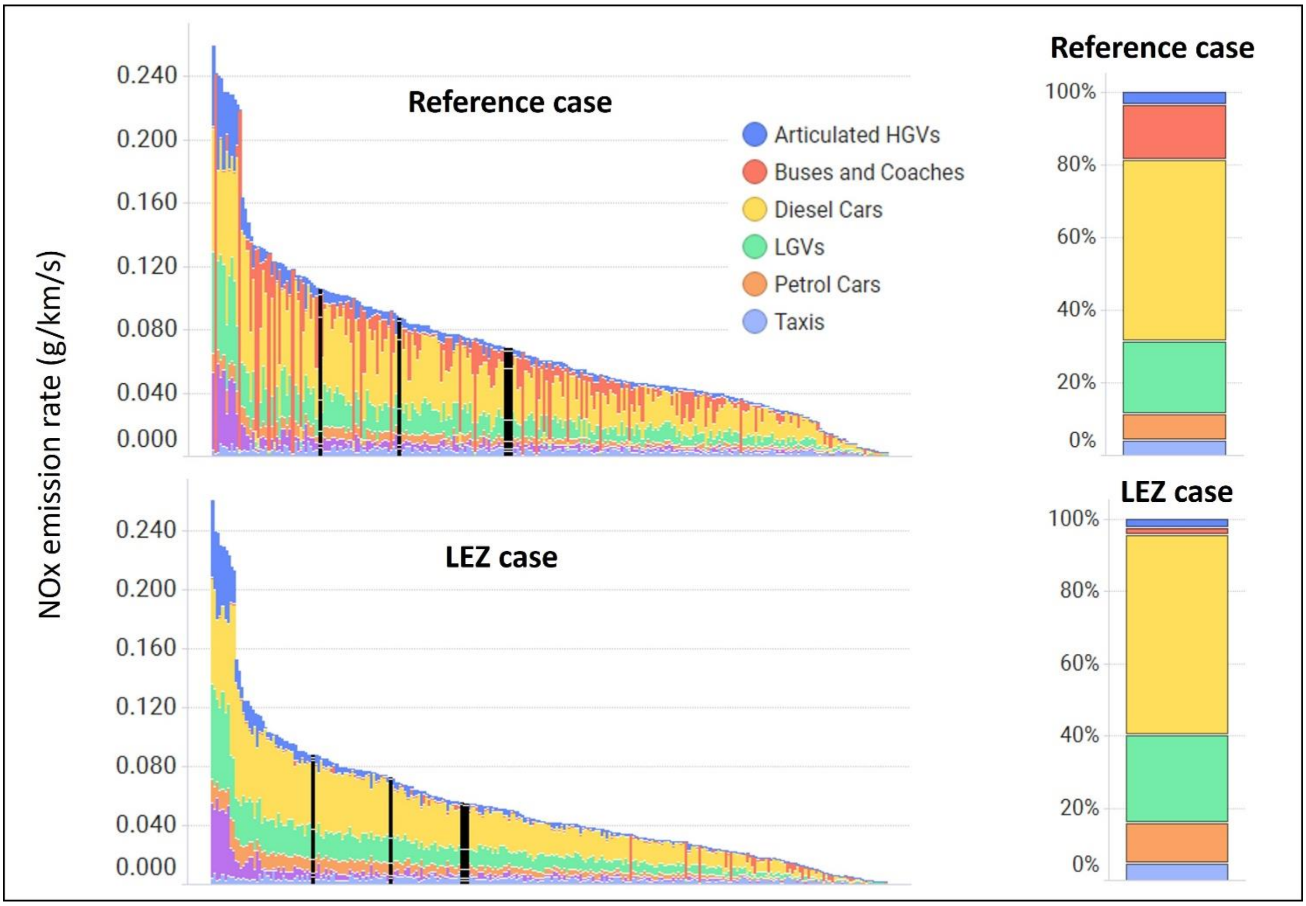

Figure 15: Source attribution of vehicle emissions on Lochee Road as highlighted on the map.

Kingsway

There are only very small changes to traffic and emissions on the Kingsway, with an increase of no more than 100 cars on sections of the road highlighted in Figure 16. The overall effect on emissions is minimal, with an overall decrease in emissions along the total length of the Kingsway of less than 1%.

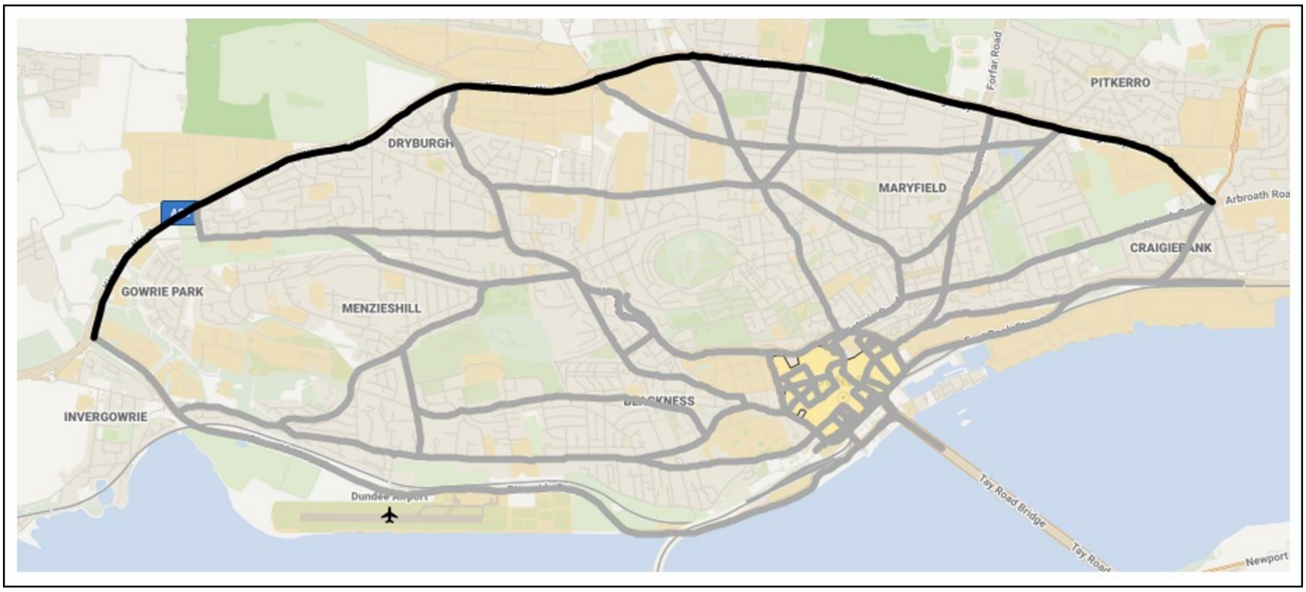

Figure 16: The Kingsway experience small changes in vehicle numbers and emissions following LEZ implementation.

Predicted changes in NO_2 concentration due to the LEZ

The air-quality model has been used to assess the impact on roadside air quality of implementing the LEZ. Figure 17 shows the change in concentration between Reference and LEZ cases, in the city centre, and Figure 18 shows annual-mean NO_2 concentrations for the LEZ case.

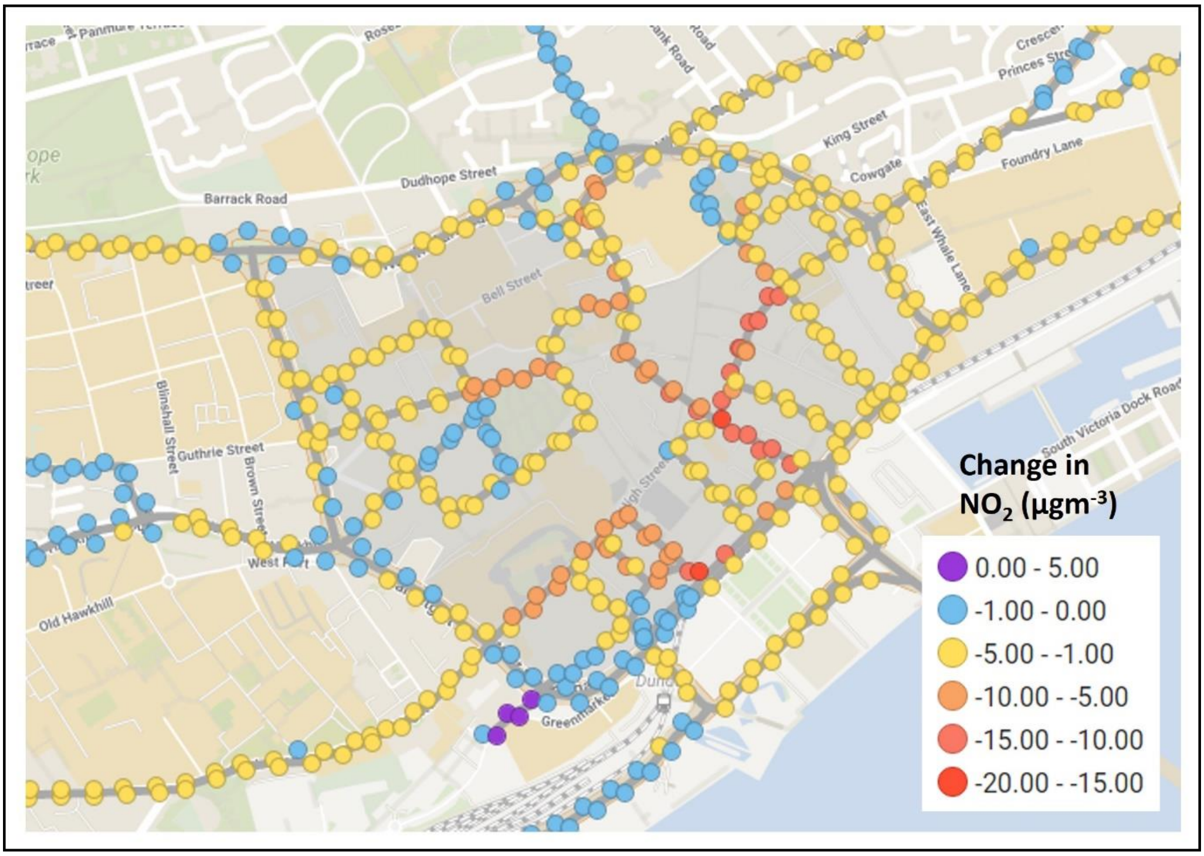

Figure 17: Relative change in NO_2 concentration between Reference and LEZ cases in the city centre. The roadside points along Greenmarket are coloured in purple due to a small increase in NO_2 concentration.

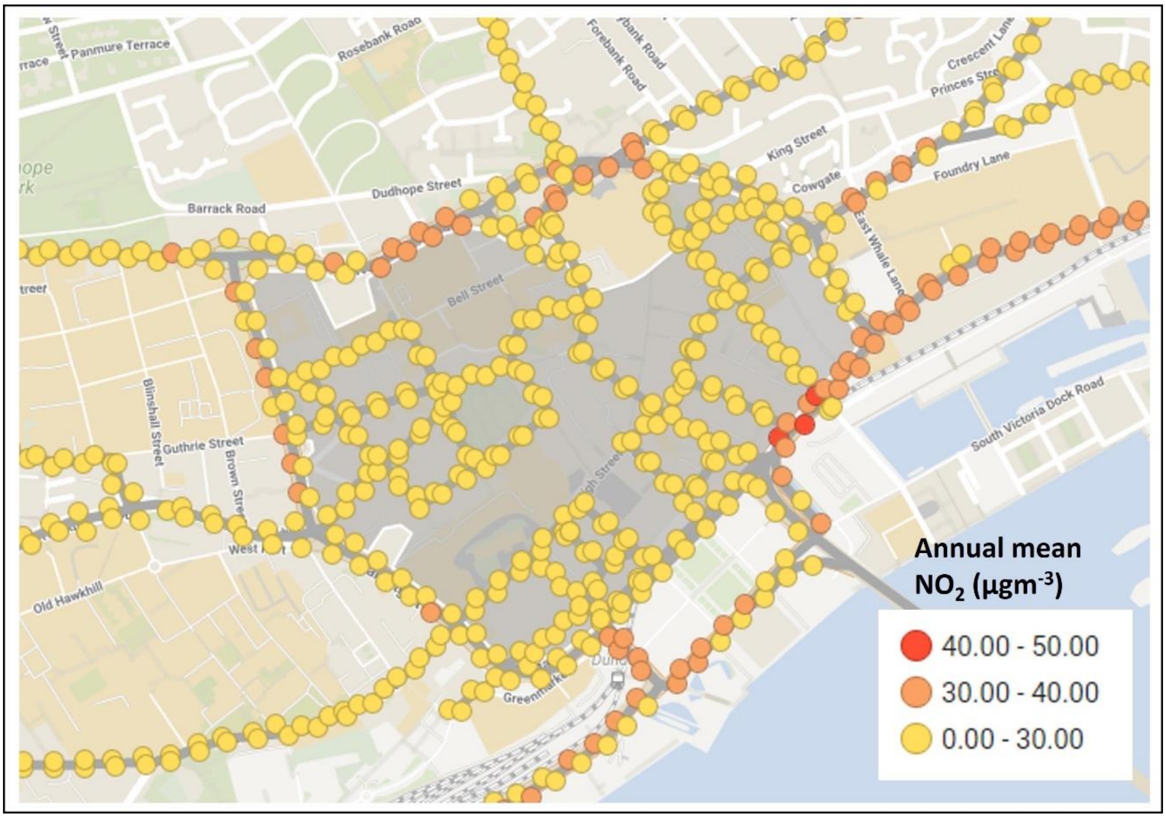

Figure 18: Predicted NO_2 concentration for the LEZ case in the city centre.

Greenmarket

The roadside points on Greenmarket are the only points in the model where concentrations are predicted to increase as a result of implementing the LEZ, as indicated in Figure 17. Despite a large percentage increase in emissions on Greenmarket, the increase in roadside concentrations is less than 0.5µgm^{-3}.

This area of the city will be re-modelled when timescales and information on future developments are firmed up. Nevertheless, total emissions remain very low, corresponding to predicted total NO_2 following implementation of the LEZ of around 25µgm^{-3}. This means that concentrations along this street remain dominated by background.

Inside the LEZ

The largest reductions in roadside concentrations due to implementing the LEZ occurs along streets most dominated by bus emissions. This includes Commercial Street and Seagate, where there is an average reduction in NO_2 of around 10µgm^{-3}. On other bus routes including Whitehall Street and Crichton Street there is an average reduction in NO_2 of around 6µgm^{-3} (Figure 17).

These predicted changes to roadside concentrations are expected to remove current exceedances of the NO_2 limit value in the city centre. Roadside points that previously exceeded or were close to exceeding an annual concentration of 40µgm^{-3}, are predicted to fall to below 30µgm^{-3} (Figure 18). The concentrations at the façade would be expected to be lower than these roadside concentrations.

Inner ring road

The small decrease in NO_x emissions around the inner ring road corresponds with a small decrease in predicted concentrations of NO_2, following implementation of the LEZ. On average there is a reduction at the kerbside of around 1µgm^{-3} (Figure 17).

There are a small number of points outside of the LEZ on Dock Street where there are predicted to be exceedances of NO_2 (Figure 18). These exceedances were present in the Reference case of the model and in Diffusion Tube observations. The LEZ is predicted to reduce concentrations on this road by ~3µgm^{-3}, such that the average concentration at roadside points along this section of road exceeds 40µgm^{-3} by less than 1µgm^{-3} for average traffic speeds. In the more precautionary reduced speed scenario, the average concentration along this section of road exceeds 42µgm^{-3} (see Appendix 1 for discussion vehicle speeds).

Given that the LEZ fleet is based on 2017 rates of compliance, it is expected that these areas of exceedance on Dock Street will not persist beyond the introduction of the LEZ.

Lochee Road

There are only small changes in predicted concentrations of NO_2 on Lochee Road, with a maximum decrease of 2µgm^{-3} (Figure 19) for the city centre only LEZ. Reductions of between 1.5µgm^{-3} – 2µgm^{-3} are predicted in the region of the automatic monitor and the diffusion tubes on Lochee Road / Logie Street that exceeded NO_2 limit values in 2019.

The potential for future NO_2 exceedances along Lochee Road will depend partly on the extent to which traffic levels return to pre-COVID levels.

Figure 19: Relative change in NO2 concentration between Reference and LEZ cases on Lochee Road.

Figure 20 shows predicted changes to concentrations of NO_2 across the entire model domain, confirming that there are only small changes outside of the inner-ring-road zone.

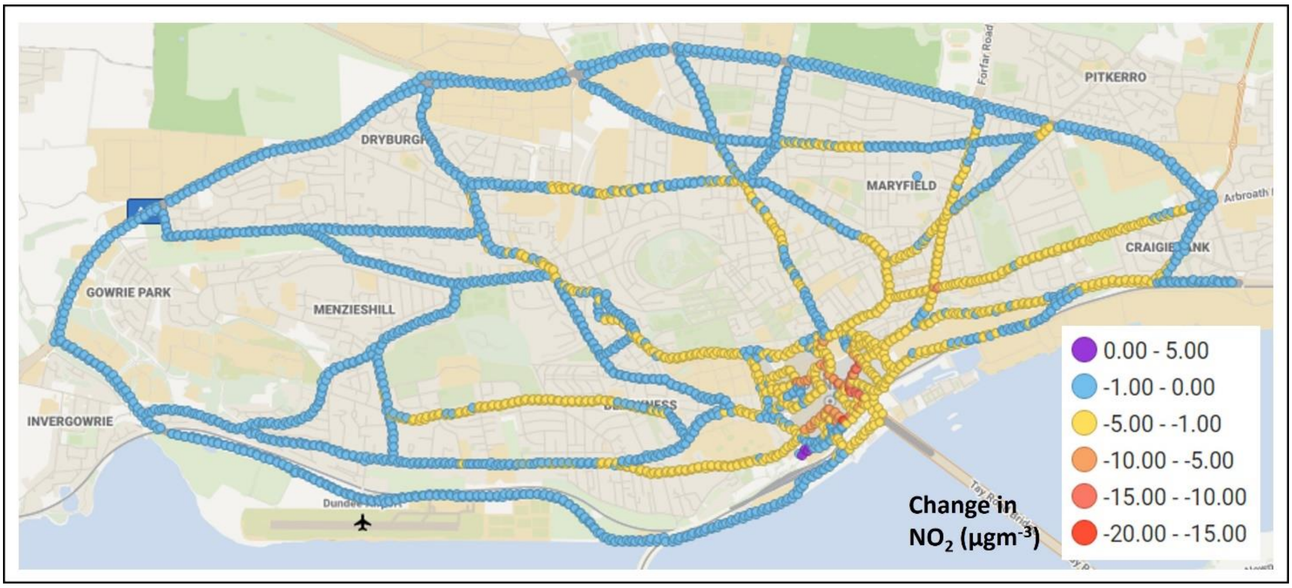

Figure 20: Relative change in NO2 concentration between Reference and LEZ cases across the entire model domain.

Detailed modelling at Façade receptors

The areas of exceedance on Dock Street have been investigated in more detail, due the presence of existing or planned ground/first floor residential properties. These have been represented in the model by additional receptors located 1m in distance from the edge of the building. This means that these receptors are 2 – 5m further away from the road than the roadside points (Figure 21). The annual mean NO_2 concentration does not exceed 40µgm^{-3} at any of these receptors. The average concentration along this stretch of road is just below 38µgm^{-3} for average traffic speeds and just under 40µgm^{-3} for the reduced speed scenario (see Appendix 1 for discussion vehicle speeds).

Natural turnover of the fleet that is expected to have occurred since the ANPR data was collected in 2017 will contribute to further reductions in NO_2 concentrations on this road.

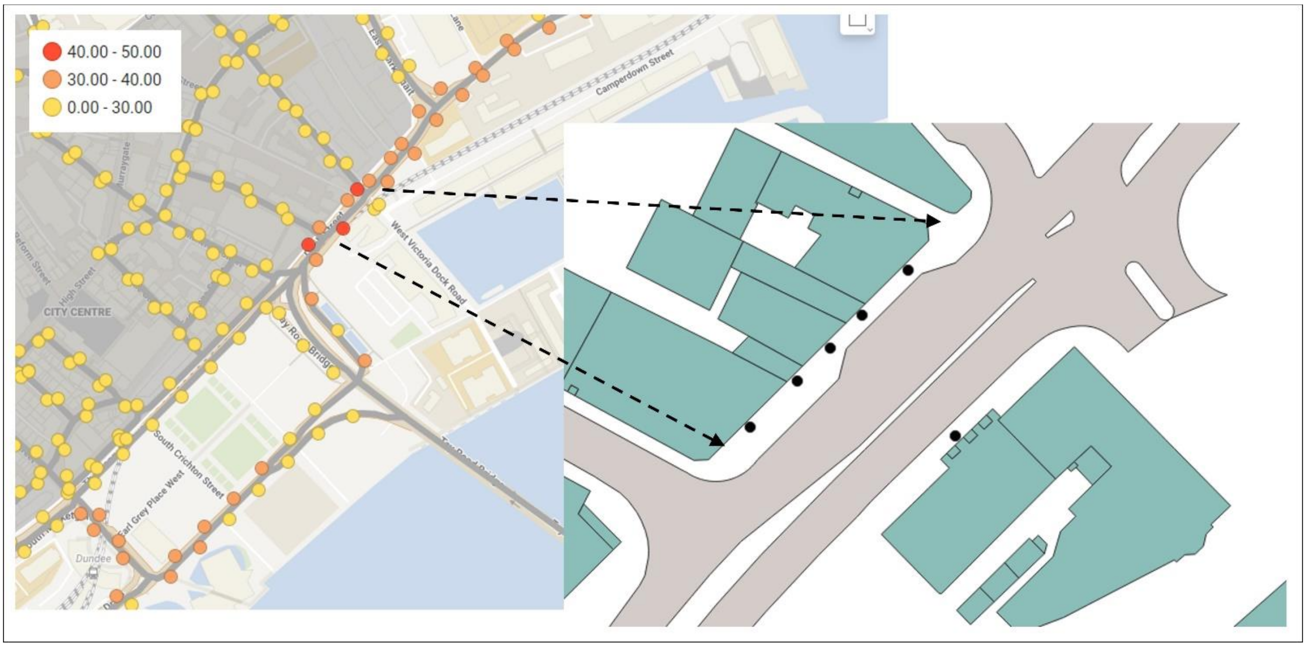

Figure 21: Black markers show the location of detailed façade receptors in the model, located 1m from the building edge, at a height of 1.5m.

There is an additional development planned for a currently empty site north of Dock Street and east of Trades Lane. This will be located in a more open part of the road network where average roadside NO_2 concentrations in the 2017 model are 34µgm^{-3} for average traffic speeds, and 36µgm^{-3} for the more precautionary reduced speed scenario (see Appendix 1 for discussion vehicle speeds). The model will be re-run for a future fleet year to include this development when more information is available or when development timescales are firmed-up.

Contribution to NO_X by vehicle type following LEZ implementation

The air-quality model has been used to show how the annual mean concentration of NO_x is made up by contributions by different types of vehicles, following implementation of the LEZ.

Figure 22 shows roadside points that have been selected around Lochee Road, as highlighted in black. The corresponding bar charts show the NO_x contribution from different vehicles. Diesel cars contribute over half of the NO_x at these points, and over half of the NO_x can be attributed to non-compliant vehicles.

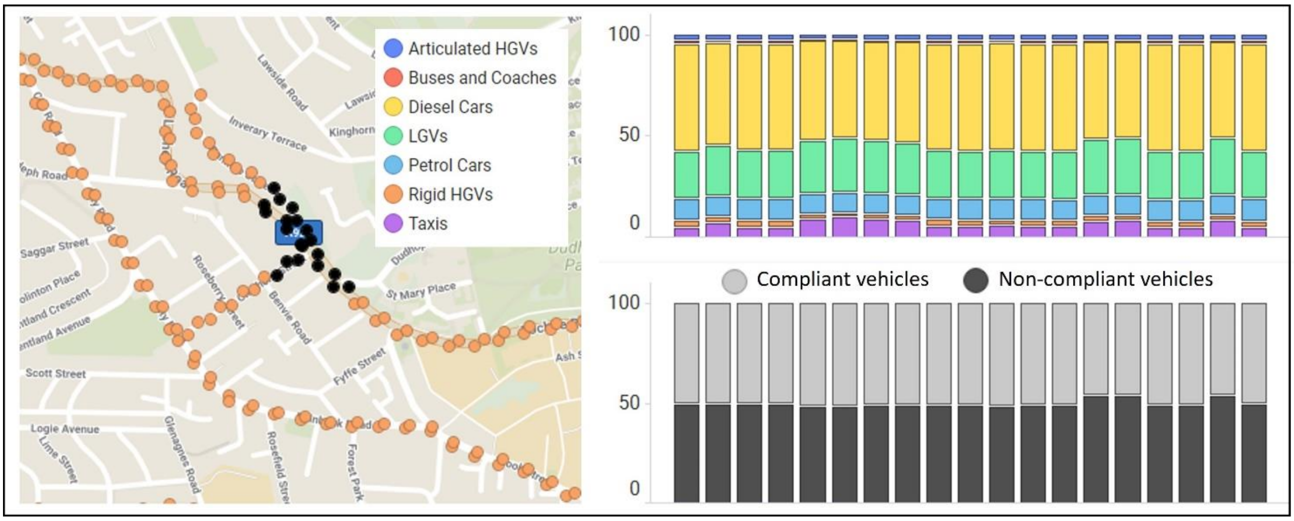

Figure 22: The contribution to modelled NO_x concentrations from different types of vehicle, at roadside points on Lochee Road.

Along the Kingsway, the contribution from different types of vehicles is more evenly distributed between diesel cars, light good vehicles and heavy good vehicles (Figure 23). The overall contribution from non-compliant vehicles in around 75%.

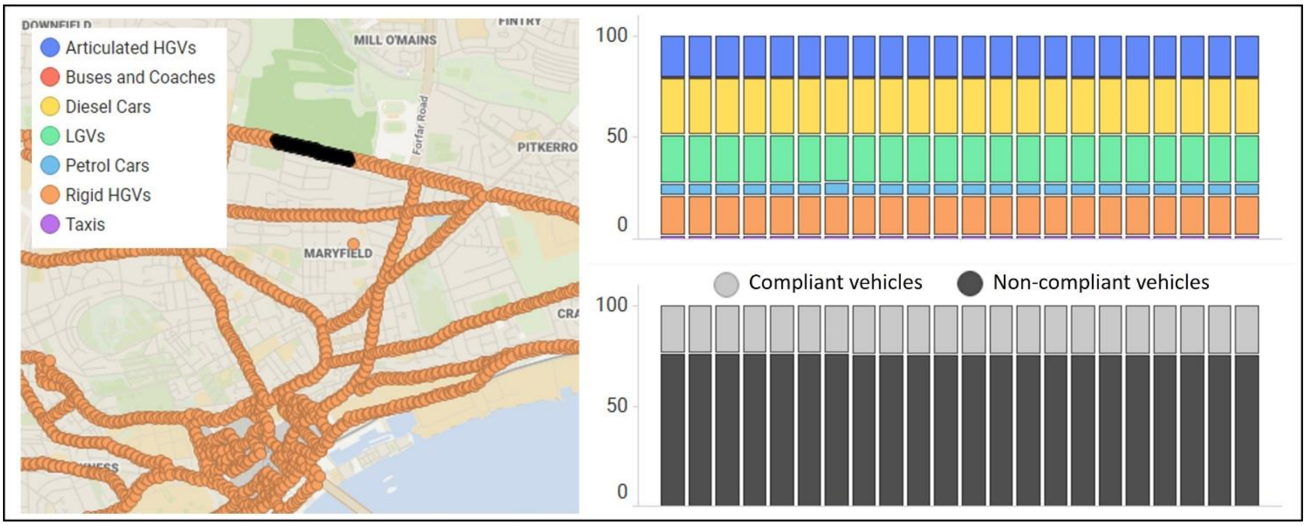

Figure 23: The contribution to modelled NO_x concentrations from different types of vehicle, at roadside points on the Kingsway.

All vehicle emissions inside the LEZ are from compliant vehicles. This has been shown to contribute to a significant reduction in predicted roadside NO_2 concentrations inside the LEZ. However, Figure 24 shows that roadside receptors inside the LEZ continue to receive a contribution of NO_x from non-compliant vehicles, outside of the LEZ. This varies depending on the distance of the receptor from the LEZ boundary, but remains in the region of 10 – 30%.

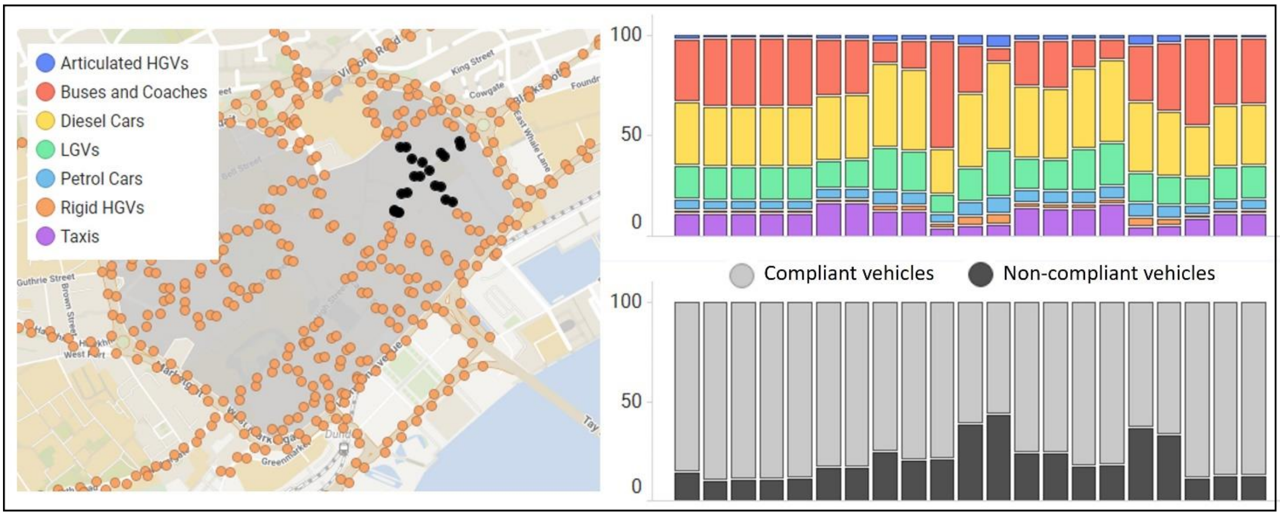

Figure 24: The contribution to modelled NO_x concentrations from different types of vehicle, at roadside points near Seagate.

Predicted changes in PM_{10} emissions due to the LEZ

The predicted change in PM_{10} emissions due to implementing the LEZ have been explored by comparing rates of vehicle tailpipe emissions between the Reference and LEZ cases. However, these emissions have not been used to predict concentrations of PM_{10}. Roadside concentrations of PM_{10} are dominated by non-tailpipe emissions, including brake and tyre-wear and re-suspension from the road surface. It is difficult to quantify the rates of these 'non-tailpipe' emissions and therefore model predictions of PM_{10} concentrations would be associated with high levels of uncertainty.

There are large reductions in PM_{10} tailpipe emissions as a result of implementing the LEZ. The largest reductions occur inside the LEZ, as shown by the roads highlighted black in Figure 25. This scale of reduction is greater than would be expected to occur in PM_{10} concentration data, due to the contribution of non-tailpipe emissions, as discussed above.

Figure 25: Ranked changes in PM_{10} emissions (%) on all roads. The greatest reductions occur inside the LEZ as highlighted in black.

Figure 26 shows the change in PM_{10} emission rates (g/km/s) between Reference and LEZ cases by vehicle type. This confirms that the largest reductions in tailpipe PM_{10} are associated with roads dominated by bus emissions.

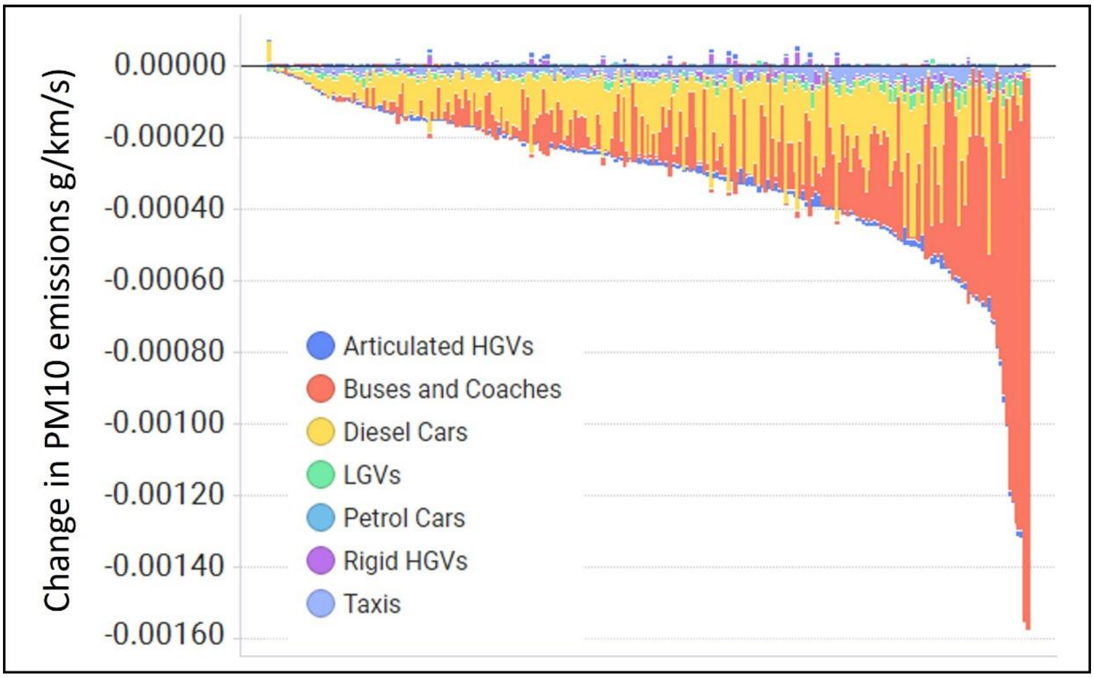

Figure 26: Predicted change in PM_{10} emissions following implementation of the LEZ, by vehicle type.

Tailpipe PM_{10} emissions are predicted to increase only on Greenmarket, where previous analysis has shown that total traffic levels will remain low following implementation of the LEZ. The roads highlighted in black in Figure 27 show Greenmarket, along with the roads predicted to see the smallest reduction in PM_{10} tailpipe emissions.

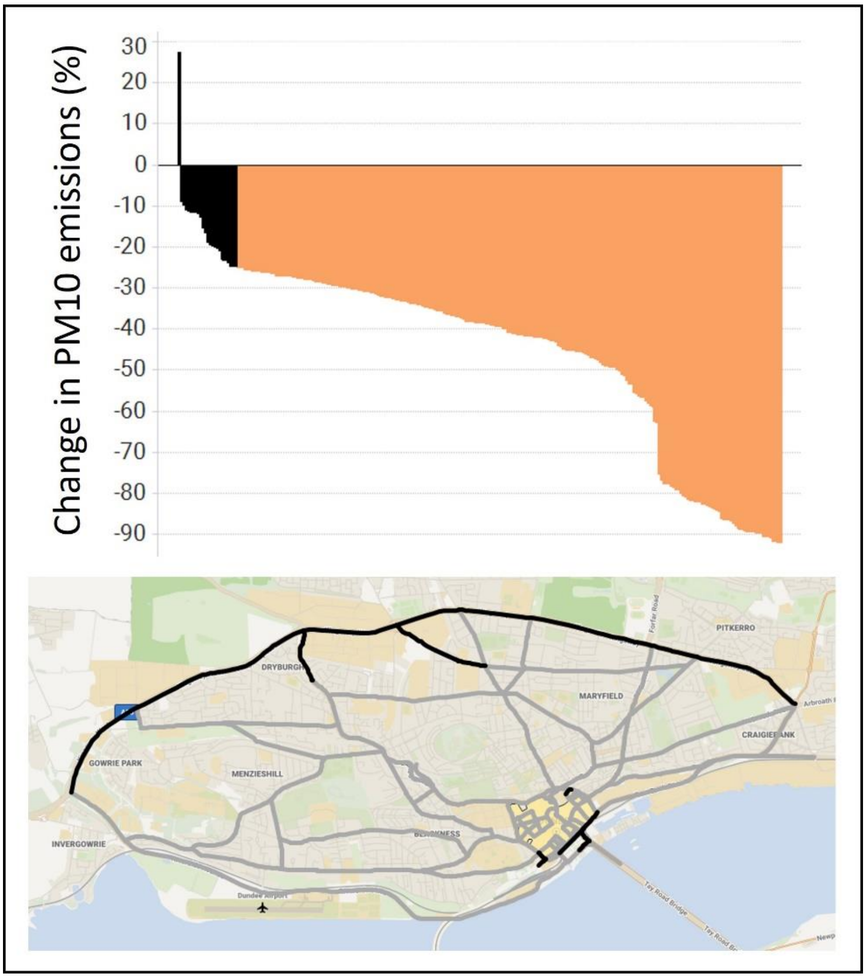

Figure 27: Ranked changes in PM_{10} emissions (%) on all roads. The smallest reductions occur on the roads highlighted in black. Emissions are predicted to increase on Greenmarket only.

References

Dundee City Council, 2005. *Local Air Quality Management - Detailed Assessment Report,* s.l.: s.n.
Dundee City Council, 2009. *LAQM and Detailed Further Assessment 2009,* s.l.: s.n.
SEPA, 2017. *Aberdeen Air Quality Modelling Pilot Project Technical Report,* s.l.: s.n.
SEPA, 2021. *Dundee LEZ Emissions Report,* s.l.: s.n.
SYSTRA, 2019a. *Dundee Greater City Base Paramics Model Development Report,* s.l.: s.n.
SYSTRA, 2019b. *Dundee Low Emission Zone. National Low Emission Framework - Interim Stage 2 Assessment,* s.l.: s.n.
SYSTRA, 2020. *Dundee Greater City Centre Reference Case Note,* s.l.: s.n.
SYSTRA, 2021. *Dundee Microsimulation Model LEZ Option Testing Note,* s.l.: s.n.

APPENDIX 1

Air Quality Modelling Verification

The methods for air-quality modelling implemented here are outlined in the National Modelling Framework. This includes representing background concentrations to account for sources of NO_2/NO_X that are not explicitly modelled. The availability of appropriate background data in each city being examined under CAFS varies, and it may not be representative of all parts of the model domain. For this reason, the methodologies for representing background may also vary.

The Dundee model has been run for 4 different background scenarios:

1. Observed hourly concentrations from Dundee Mains Loan – the closest Urban background automatic monitor
2. Observed hourly concentrations from Bush Estate – the closest Rural background automatic monitor, in addition to 1km gridded emissions from the National Atmospheric Emissions Inventory (NAEI) to account for other local sources of pollution
3. Observed annual mean NO_2 from Murraygate – an Urban background diffusion tube located inside the proposed LEZ
4. Observed hourly concentrations from Errol Place – an Urban background monitor in Aberdeen.

In 2017, the annual-mean concentration of NO_2 at the Urban Background automatic monitor (Mains Loan) was $12\mu gm^{-3}$. This is notably lower than the Urban Background diffusion tube located inside the proposed LEZ (Murraygate) which recorded an annual mean of $20\mu gm^{-3}$. While it is expected that concentrations would vary between these two locations it highlights the uncertainty in identifying the most appropriate source of background data.

It is notable that the annual mean NO_2 concentration measured at Mains Loan is lower than all other Urban background sites across Scotland, including Falkirk and Grangemouth (Figure 28). This suggests that the Mains Loan automatic monitor may be less representative of city centre urban background concentrations than other urban background monitors are of their respective city centre urban areas.

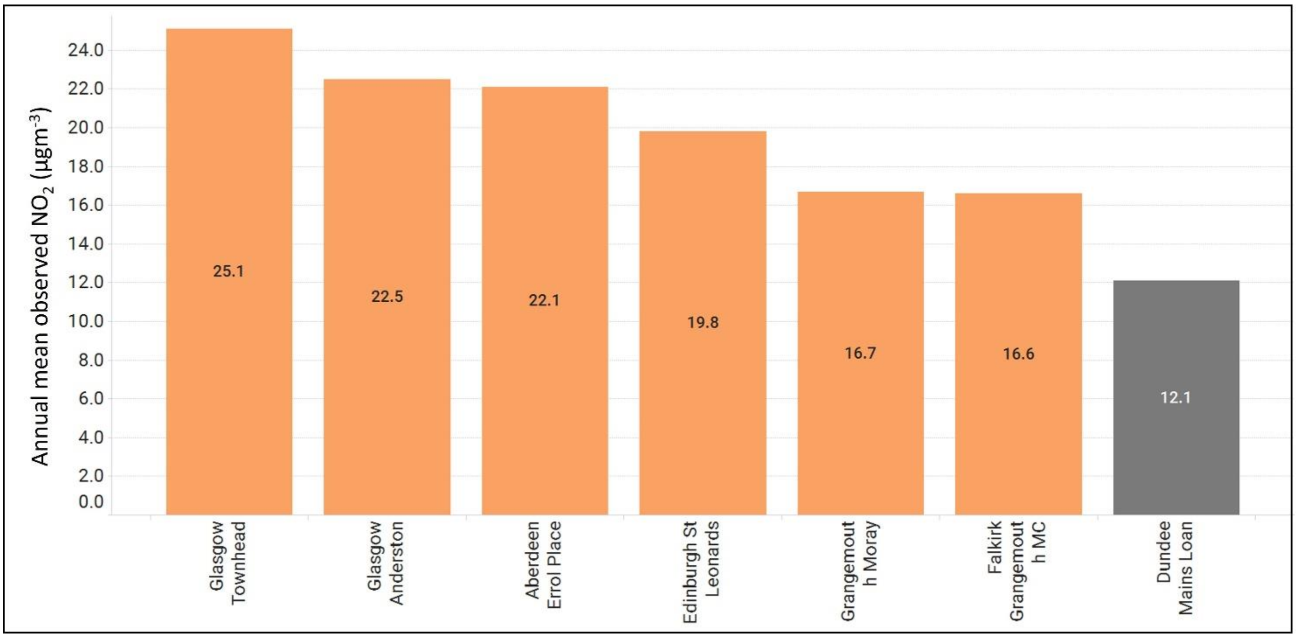

Figure 28: Annual mean NO_2 in 2017 at all Scottish Urban background automatic monitors.

Scenario 4 listed above uses hourly data from Aberdeen Errol Place. This is the next closest Urban Background monitoring station that provides continuous hourly data. In 2017 it has an annual mean of 22µgm^{-3}, which is similar to the Murraygate Dundee Diffusion tube.

Figure 29 shows the predicted annual mean concentration of NO_2 at each of the roadside points in the model, ranked from high to low, for each of the 4 background scenarios described above. This confirms that predicted concentrations vary significantly depending on which background method is used. The annual mean concentrations used in the 4 scenarios are summarised in Table 1.

Table 4: Annual mean concentrations used in the 4 scenarios described above. Note that scenario 2 includes an additional background concentration from gridded emissions.

Scenario	Annual mean NO_2	Monitor	Monitoring method
1	12µgm^{-3}	Dundee Mains Loan	Automatic monitor (Urban)
2	5µgm^{-3}	Bush Estate	Automatic monitor (Rural)
3	20µgm^{-3}	Dundee Murraygate	Diffusion tube (Urban)
4	22µgm^{-3}	Aberdeen Errol Place	Automatic monitor (Urban)

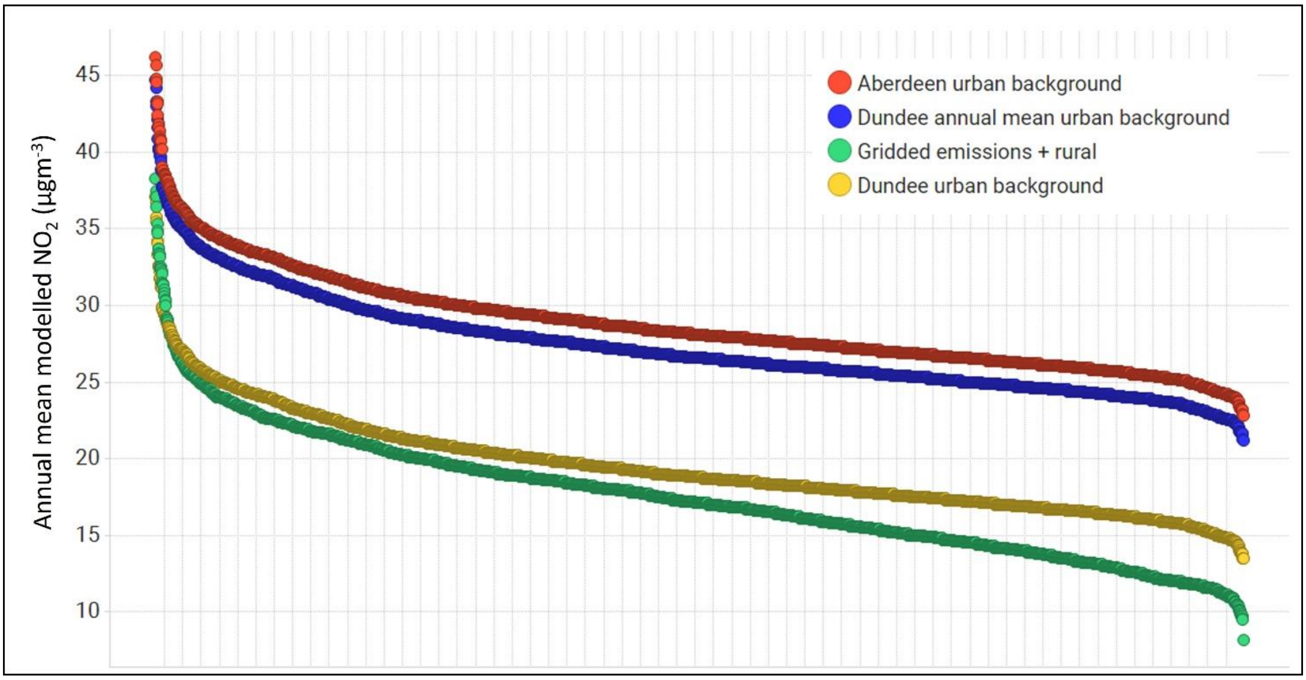

Figure 29: Ranked NO_2 predictions of NO_2 at roadside points for 4 background scenarios.

Concentrations calculated using the Mains Loan Automatic monitor are comparable to the approach using gridded emissions (Scenario 2). However, these are notably lower when compared to the concentrations calculated using the Murraygate diffusion tube as background (Scenario 3). Given that the Murraygate diffusion tube is located inside the LEZ, but not directly impacted by nearby traffic, this is likely to be more representative of city centre background.

There is a preference to use data from Automatic monitoring stations where possible, due to Quality Assurance and Control procedures that are applied to the data, and the high temporal resolution of the measurements. The range of predicted concentrations calculated using Aberdeen Automatic monitor are similar to those using the Murraygate diffusion tube (Figure 29). For these reasons hourly background concentrations from Aberdeen Errol Place (Scenario 4) are used in all subsequent analyses.

Model performance has been evaluated for two traffic speed scenarios:

1. Average speed from the Paramics model
2. Average speeds from the Paramics model are used except where exceeding 20km/h. The speed on these roads is set to 20km/h. This has the effect of increasing vehicle emissions slightly to give a more precautionary approach. It may better reflect situations where there is frequent stopping and starting of traffic close to bus stops or junctions. This change in speed tends to be small inside the LEZ, e.g. a 2km/h reduction in Seagate, and no reduction on

Meadowside where average speeds are 17km/h. The change is greater outside the LEZ, e.g. part of Lochee Road where speed changes from 29 to 20km/h.

Performance at Automatic monitors

Model predictions of annual mean NO_2 are compared against 6 automatic monitors in Dundee, using background concentrations from Aberdeen Errol Place (Figure 30) and using Dundee Mains Loan (Figure 31). Results are presented for the average and reduced speed scenarios described above.

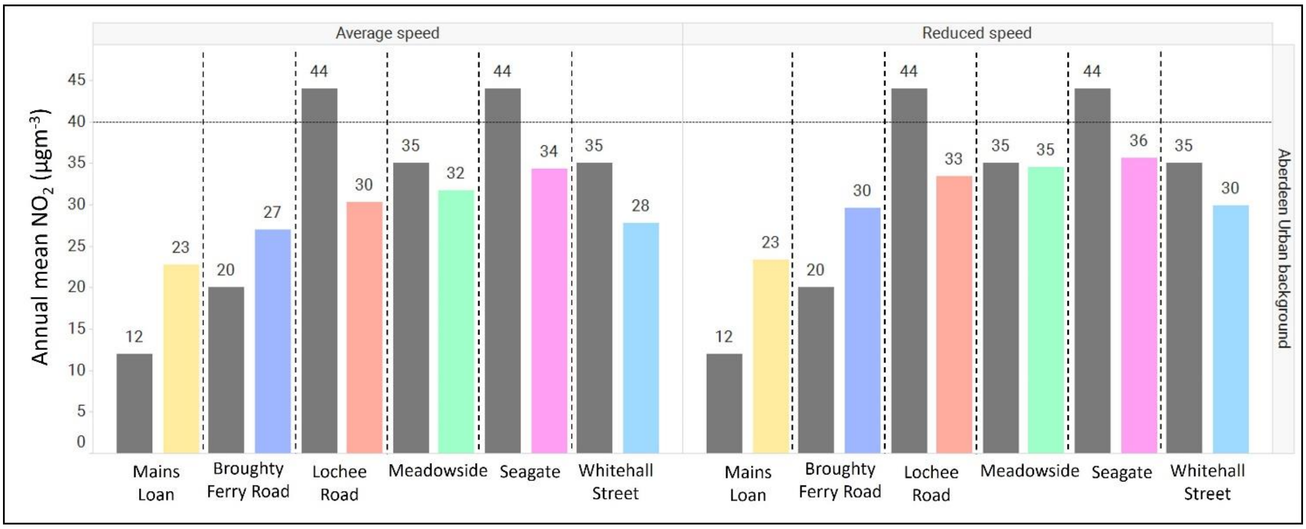

Figure 30: The annual-mean NO_2 measured at the Automatic monitors (in grey) are compared against the model prediction at that location, using Aberdeen Urban Background (Errol Place) for 2 speed scenarios.

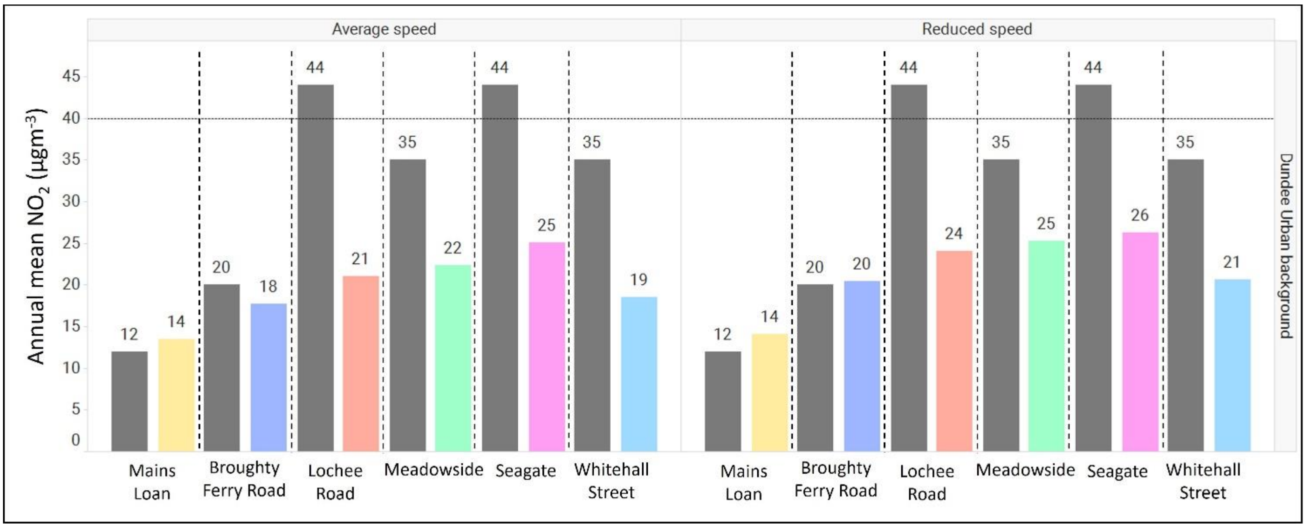

Figure 31: The annual-mean NO_2 measured at the Automatic monitors (in grey) are compared against the model prediction at that location, using Dundee Urban Background (Mains Loan) for 2 speed scenarios.

The agreement between observations and model predictions shown in Figures 30 and 31 varies between monitoring stations, confirming that a single background monitoring station does not accurately represent all parts of the model domain. At the Broughty Ferry Road monitor, there is good model agreement when using Dundee Urban background. This location is not heavily trafficked and the annual mean NO_2 concentration is dominated by background. In other locations inside the inner-ring road and on more heavily trafficked roads the agreement is best when using Aberdeen Urban background.

There remains a general tendency to under-estimate concentrations at the automatic monitors, most significantly at Lochee Road. This is a complex part of the road network which would benefit from a separate more detailed model. This is a one-sided street canyon consisting of a 4-storey building, but with tall trees on the opposite side of the road. Lochee Road splits into 3 lanes adjacent to the monitor for allow for traffic to queue before turning into Rankine Street. There is also a gradient.

A previous version of the model adjusted emissions rates for gradients and investigated the use of model barriers to account for roadside trees. However, these did not substantially reduce the degree of model under-estimation at this location. A separate model also used Computation Fluid Dynamics (CFD) to investigate dispersion in the vicinity of the monitor, highlighting complex air flow. These factors will be investigated again in future work.

Some previous ADMS modelling studies in Dundee used an annual mean background concentration based on the average of more than 1 passive diffusion tube monitor. Through a process of model verification, these studies have applied correction factors to the modelled road-NO_x contribution in order to achieve better agreement between model results and observations in the Lochee Road region. These factors have been in the region of 3-6 (2005 and 2009 reports).

Performance at Diffusion tubes

Diffusion tube results from 2017 indicate that there are likely to be exceedances of the annual mean limit value of NO_2 in and around the LEZ area. Automatic monitoring stations in the LEZ confirm exceedances along Seagate but the station on Whitehall Street was below $40 \mu gm^{-3}$ ($35 \mu gm^{-3}$) in 2017 (Figure 32).

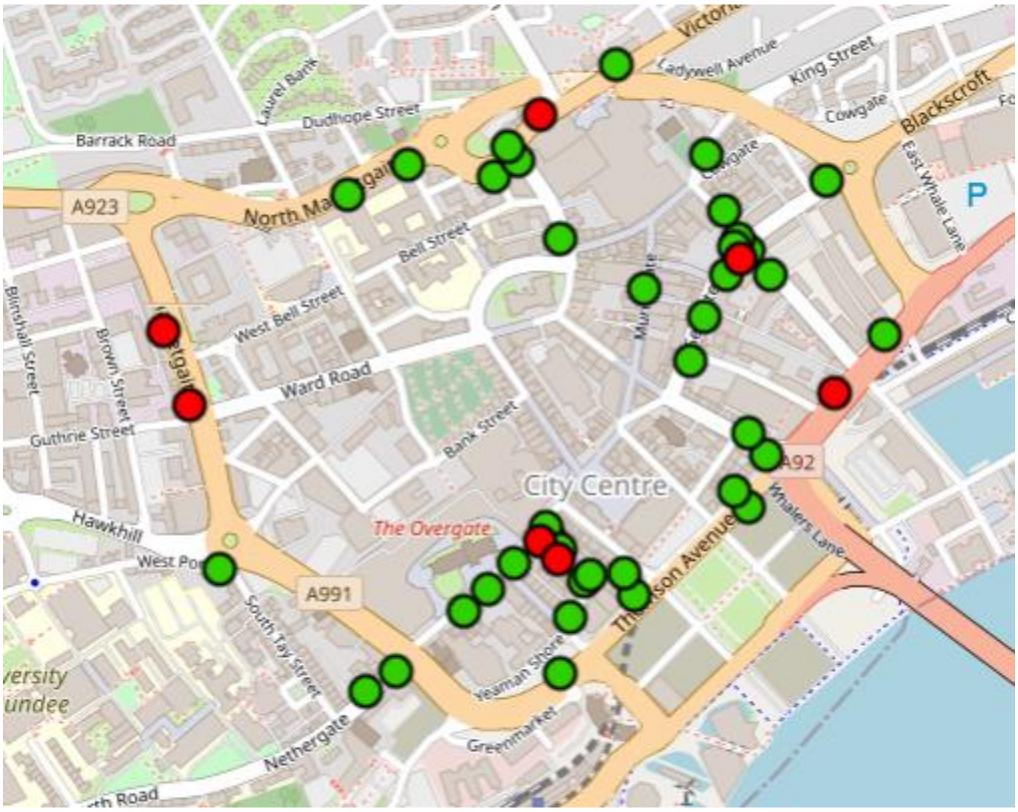

Figure 32: Diffusion tubes results in 2017, from www.scottishairquality.scot.

Model predictions of annual average NO_2 are shown in Figure 33, using the average Paramics traffic speed and Figure 34 for the reduced speed scenario. The highest concentrations are found in areas also highlighted by air-quality monitoring, including part of Victoria Road, Seagate and parts of Dock Street. The model does not indicate exceedances along West Marketgait.

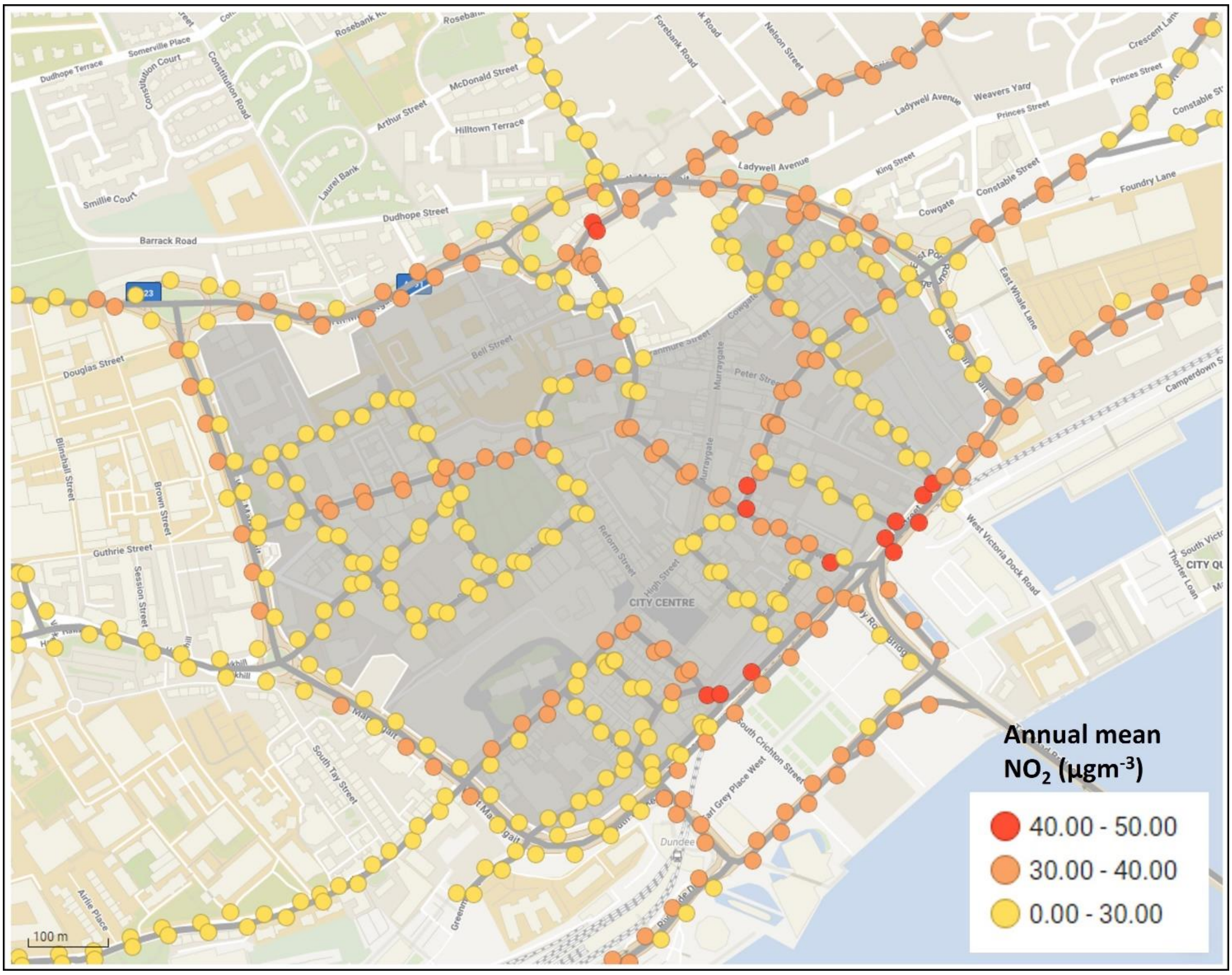

Figure 33: Modelled annual-mean concentrations of NO_2 in 2017 (using Aberdeen Urban background) for the Reference case for average vehicle speeds.

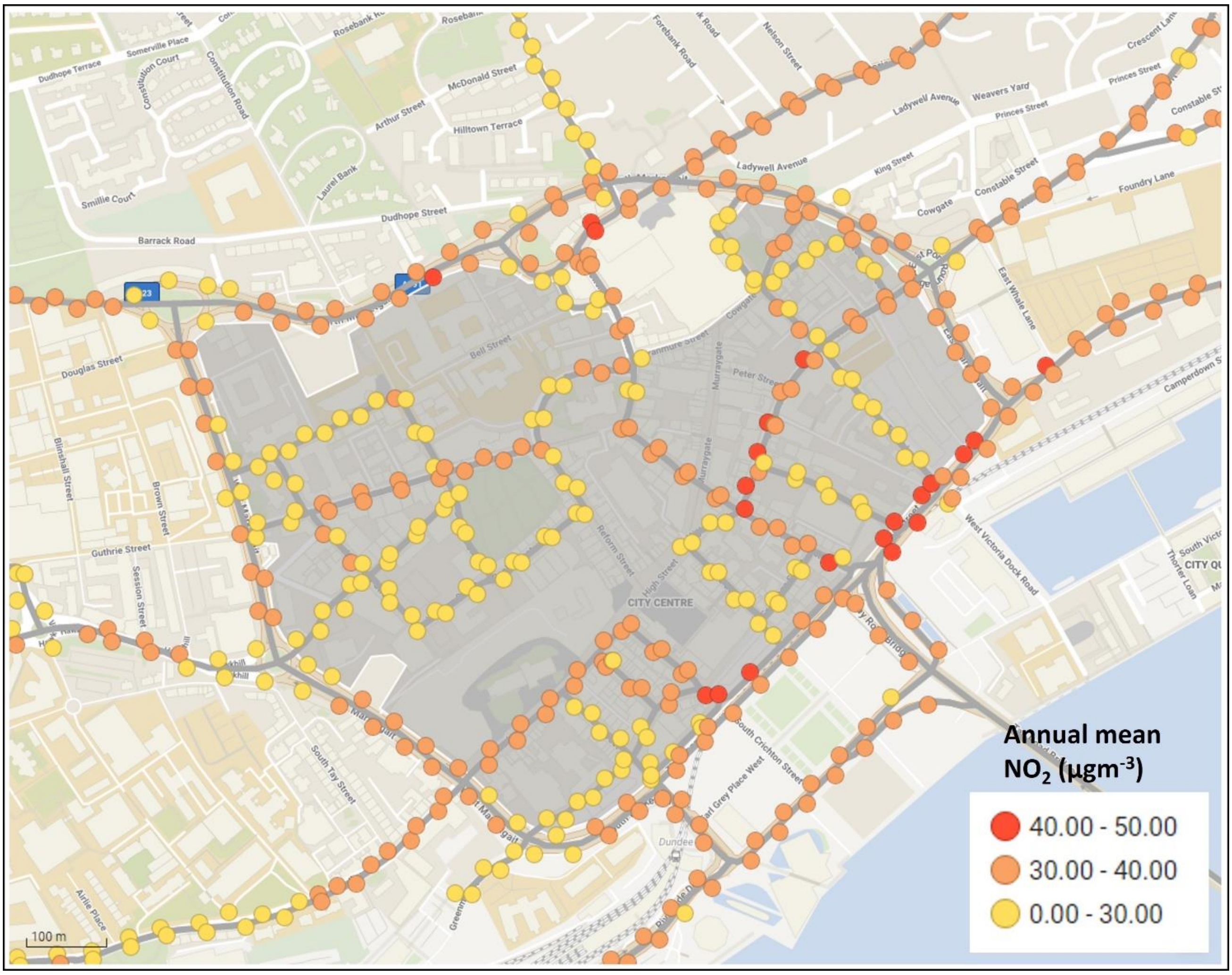

Figure 34: Modelled annual-mean concentrations of NO_2 in 2017 (using Aberdeen Urban background) for the Reference case for reduced vehicle speeds.

Gaussian models such as ADMS are not able to replicate the full complexity of dispersion in an urban street canyon. Air-quality observations which have been made at a single point are therefore compared here against predicted concentrations at multiple nearby roadside points. This accounts for model uncertainties which means observed concentrations may not be re-produced by the model in the monitored location.

Table 5: A comparison of NO_2 diffusion tube measurements (μgm^{-3}) against model predictions at roadside points.

Location	Observed NO_2 concentrations	Modelled concentrations: average speeds	Modelled concentrations: reduced speeds
Seagate	30 - 43	34 - 41	36 - 41
Dock St (57)	49	41 - 46	43 - 49
Victoria Rd / Hilltown	52	40 - 45	43 - 48
Whitehall Street	35 - 41	28 - 30	30 - 32
Lochee Road	35 - 48	28 - 34	31 - 37

The Murraygate diffusion tube is located on a pedestrianised street, around 90m from the nearest traffic source. It is not directly affected by vehicle emissions and is therefore representative of urban background concentrations. In 2017 it measured 20μgm^{-3}, whilst at this location the model predicts a value of 24μgm^{-3}. The background concentration used in the model was 22μgm^{-3}, confirming that this location is only minimally impacted by direct vehicle emissions.

A comparison of diffusion tube measurements and roadside point predictions confirms that the model generally tends to under-estimate concentrations, including on Whitehall Street and Lochee Road. However, when considering modelled concentrations at a range of roadside points it is evident that other areas of exceedance are captured by the model. Areas of exceedance on Seagate are predicted, as well as some of the highest concentrations in the city around Dock St and Victoria Street.

For information on accessing this document in an alternative format or language please contact SEPA by emailing to equalities@sepa.org.uk

If you are a user of British Sign Language (BSL) the Contact Scotland BSL service gives you access to an online interpreter enabling you to communicate with us using sign language.

http://contactscotland-bsl.org/

www.sepa.org.uk