APPENDIX 1

Cardiff Council Clean Air Feasibility Study
Final Plan

June 2019

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Acronyms, Definitions and Notes

AADT	Annual Average Daily Traffic
ANPR	Automatic Number Plate Recognition
AQAP	Air Quality Action Plan
AQMA	Air Quality Management Area
CASAP	Clean Air Strategy and Action Plan
CAZ	Clean Air Zone
CBA	Cost Benefit Analysis
CCBTF	Cardiff Clean Bus Technology Fund
CCR	Cardiff Capital Region
CCW	City Centre West
CCN	City Centre North
CO	Carbon Monoxide
CSF	Critical Success Factor
Defra	Department for Environment, Food and Rural Affairs
DfT	Department of Transport
DIA	Distributional Impact Assessment
DPFs	Diesel Particulate Filters
EV	Electric Vehicle
FBC	Full Business Case
fNO_2	NO_2 Fraction
HGV	Heavy Goods Vehicle
HIA	Health Impact Assessment
JAQU	Joint Air Quality Unit
LAQM	Local Air Quality Management
LES	Low Emission Strategy
LEV	Low Emission Vehicle
LGV	Light Goods Vehicle
LowCVP	Low Carbon Vehicle Partnership
LTP	Local Transport Plan
NO_2	Nitrogen Dioxide
NPV	Net Present Value

O_3	Ozone
ODB	Organisational Development Board
OBC	Outline Business Case
OLEV	Office for Low Emission Vehicles
PM2.5	Particulate matter with a size (diameter) generally less than 2.5 micrometres (2.5 thousandths of a millimetre)
PM10	Particulate matter with a size (diameter) generally less than 10 micrometres (10 thousandths of a millimetre)
PCM	Pollution Climate Mapping
PPW	Planning Policy Wales
PSB	Public Service Board
PQA	Project Quality Assurance
PMO	Project Management Office
SCR	Selective Catalytic Reduction
SEWTM	South East Wales Transport Model
SO_2	Sulphur Dioxide
TRC	Traffic Regulation Condition
TUBA	Transport Users Benefit Anlaysis
ULEV	Ultra-Low Emission Vehicle
WFG	Well-being of Future Generations (Wales) Act 2015
μgm^{-3}	Micrograms per cubic metre

Definitions
"CASAP measures" is also referred to as the preferred option or non-charging measures All refer to a final package of non-charging mitigation measures which are an accumulation of identified mitigation measures developed from the long list of measures outlined in the Clean Air Strategy and Action Plan, as well as from followed up detailed air quality modelling.

CAZ 1 is a variant of a Charging Clean Air Zone.
Cardiff Council is normally referred to in this report as "Cardiff Council", but sometimes as "the Council".

Welsh Government- Environment Act 1995 (feasibility study for Nitrogen Dioxide Compliance) Air Quality Direction 2018- referred to as "the direction" throughout this report.

Notes regarding appendices
Please note that appendices will comprise separate documents for the FBC, due to their size. They will be available as separate documents via the Council's website, following publication of this FBC.

Executive Summary

Background
In response to a legal direction Cardiff Council received from Welsh Government- Environment Act 1995 (feasibility study for Nitrogen Dioxide Compliance) Air Quality Direction 2018- the Council must:

- Submit "initial scoping proposals"- by March 2018- to set out how Cardiff Council would undertake a feasibility study.

- Submit an "initial plan", by September 2018, to set out the case for change and develop options for measures that the local authority will implement to deliver compliance with Clean Air targets in the shortest possible time.

- Submit the "final plan", no later than the 30th June 2019, to set out in detail the preferred option for delivering compliance in the shortest possible time, including a full business case

The Council has been following a legal process to comply with the direction. As part of this process the Council submitted its "initial scoping proposals" in March 2018 and its Initial Plan, to Welsh Government in September 2018, as approved by Cabinet 15th November 2018 which presented the results of the initial baseline assessment of the Clean Air Feasibility Study. The Cabinet approved an Outline Business Case in March 2019, which set out the preferred option being a package of non charging measures.

This report presents the Final Plan and Full Business Case (FBC) for the preferred option which is a package of measures. By implementing the preferred option, the Council can achieve compliance in the shortest possible time and this preferred option needs to be approved by Cabinet

Preferred Option
The Interim Plan presented to Cabinet in March 2019, indicated that the Councils preferred option was a package of non-charging measures over a charging Clean Air Zone. The report recommended that a revised shortlist of non charging measures be considered as the preferred option and included:

- Implementation of Electric Buses ;
- Bus Retro Fitting Programme;
- Taxi Licensing Policy and Mitigation Scheme;
- City Centre Transport Improvements; and
- Active Travel Measures

In order to show transparency on allow public/ stakeholder engagement on the Councils proposed preferred option a full public consultation on the proposals was undertaken. The Consultation consisted of detailed information on the preferred option through the Councils website. An online survey was developed, which could be accessed from a page on the Council website, which provided the background information on the proposals. This was distributed to members of the Council's Citizens' Panel, consisting of over 5,000 residents across the city, and to a list of key stakeholders.

Public engagement events were also held, giving members of the public an opportunity to ask further details about the scheme from members of the Project team:

- April 13th: Angel Hotel;
- April 20th: Central Library;
- May 4th: Angel Hotel; and

- May 11th: Central Library

After data cleansing to remove any blank or duplicate responses, a total of **1,303** responses were received from the consultation. Overall the responses for the preferred option of non charging measures were overwhelming supportive, particular the measures targeted at improving emissions from buses and taxis.

- **96.8%** support the proposal to replace the most polluting diesel buses with electric buses;
- **90.4%** support the proposal to retrofit other polluting buses so they are upgraded to meet the latest emission standards; and
- **80.3%** support the proposed changes to taxi licensing in the city.

Considering that it was only possible to include the high level design principles of the City Centre Schemes within this consultation, the proposals were favourably received with two-thirds of respondents supporting the proposals, with just under a fifth against. Further statutory consultation will be undertaken on the detailed designs of the City Centre Schemes.

82% of the respondents to the survey were car owner/ drivers, and the majority of respondents were males (60%) aged 35-55 (45%).

<u>Results of Final Assessments</u>
This report presents the results of the final assessment and full economic appraisal including health impact assessment of the non charging measures.

Using independent analysis from external consultants with recognised expertise and a proven track record of supporting other UK Core Cities- localised air quality modelling and transport modelling was undertaken to establish the impact of the revised package of non-charging measures as to whether compliance could be achieved by 2021. As detailed in the Initial Plan baseline assessment shows that by 2021 only Castle Street would breach the EU limit value for NO_2 with concentrations of 41.1 $\mu g/m^3$ being predicted.

The package of measures have been assessed and the updated results indicate that NO_2 levels on Castle Street, reduce significantly from 41.1 $\mu g/m^3$ **to 31.9 $\mu g/m^3$** in 2021. The levels forecasted on Castle Street have reduced significantly from the results presented in the OBC. The main reason for this is, likely from the inclusion of the Castle Street Scheme which was not previously modelled.

In addition to achieving compliance on Castle Street, the impact of the package of measures has also been modelled at local air quality monitoring locations, including those locations within existing Air Quality Management Areas (AQMAs). The results of the modelling indicate that all monitoring locations are expected to have concentrations below 40 µg/m3. This is an important aspect of the assessment as it further demonstrates that the non charging measures not only deliver compliance but further improve and reduce relevant exposure in terms of LAQM across Cardiff as whole including the existing Air Quality Management Areas, and this will provide further public health benefits.

<u>Economic Appraisal and Distributional Impact Analysis</u>
An economic appraisal (cost benefit analysis) has been undertaken in line with appropriate national guidance and best practice. Any scheme to tackle air quality will impact different parts of the environment, economy and society. The economic analysis seeks to quantify and value as many of these impacts as possible given the time, resource and modelling methodologies available. In order to provide a comparative analysis the assessment on both the preferred option, that being the

package of measures, and the previously assessed City Centre Clean Air Zone presented in the Interim Plan has been undertaken.

The nature and significance of the impacts associated with the package of measures and the CAZ option vary substantially. However, both schemes have a negative Net Present Value (NPV), i.e. the costs outweigh the benefits, and the non charging measures do have a larger negative NPV (£-£306,751,560 for the measures vs £52,951,224 for the CAZ).

In terms of the preferred option the most significant proportion of the calculated negative costs (disbenefit) comes from the additional travel time as a result of the City Centre Schemes. However it has to be stressed that this is not a direct 'pocket' cost to individuals, but is a monetised value of the extra time taken to travel.

To put this into perspective the distributional analysis indicates that for 75% of the additional journey times, the increase is only 0-5 minutes, and only 1% of journey times increase by more than 10 minutes. The most affected part of the City in terms of increased journey times appears to be for journeys from the North West.

Further, the analysis undertaken to calculate this disbenefit is a very conservative estimation and has likely over calculated the true disbenefit. This is owing to the limitations of the modelling, as it has only been done for a single year and it does not take in to account the demand response. It assumes that that people only re-route and do not change modes of transport, nor does it consider the congestion improvements expected at the culmination of the roadworks. It also doesn't take account of any future transportation measures that could be introduced during the assessment period (2021-2031).

The largest disbenefit affecting the CAZ measure is the user charges which has a direct societal cost of £**87m** over the 10 year assessment period and impacts household directly.

Calculating the Net Present Value does not paint a full picture of the impacts of either scheme. There are likely to be dynamic responses to changes in congestion and new road measures introduced that cannot be accounted for. Moreover, it is important to recognise the inherent benefit that the increased reduction in air pollution beyond the limit value that the preferred option achieves.

The analysis of the package of measures shows that a real reduction in emission occur, with significant health benefits. In terms of the air quality benefits the preferred option of the package of measures significantly outweighs the air quality benefits of the CAZ option. Further the non charging measures have been shown to reduce emissions of other pollutants especially particulate matter pollution (PM2.5), whereas for the CAZ option this shows PM2.5 emissions increasing.

The Final Plan has assessed how the measures could impact various demographics through a Distributional Impact Analysis. The results indicate that the most deprived part of the population as well as the population with the highest proportion of children would see the greatest air quality improvements from the preferred option of the package of measures.

In comparison the charging scheme would lead to much greater direct costs to households due to the direct and indirect impact of the charges. The assessments show that whilst a higher income of population would disbenefit the most from the introduction of the charging scheme, this is balanced by a greater proportion of non-compliant cars own by the lower income population that would have to pay the charge

An important point in the CBA is the positive health benefits of the CASAP option in terms of improved air quality (£4.8 million benefit) and active travel benefits (£15 million benefit). In comparison the CAZ 1 option indicates an overall negative health benefit as air quality is worsening in some areas, which is counter to the overall objective of reducing air pollution to improve public health, and it does not generate any active travel benefits.

Overall the evidence suggests that the CASAP scheme should be taken forward as the preferred option because:

- It achieves compliance by the greatest margin and is robust under the sensitivity tests carried out;

- It generates the greatest health benefits from both air quality improvements and active travel benefits, compared to the CAZ option which in fact generates an overall negative health benefit;

- The benefits generated by the CASP option fall most to low income and disadvantaged groups to supports wider social goals; and

- Although the NPV is worse for the CASAP option the dominate factor driving the negative NPV is associated with some uncertainty. Also, the legal ruling in relation to compliance sets out that costs are not a material consideration in terms of achieving compliance as soon as possible.

Funding and Implementation Costs

The Welsh Government has stated that it has allocated over £20 million for an Air Quality Fund through to 2021 to help accelerate compliance with NO_2 limits and improve air quality in Wales. Welsh Government have stated that this fund will primarily be used to provide on-going support, guidance and finance to enable Cardiff Council (and Caerphilly County Borough Council) to take action to achieve compliance in the shortest possible time.

Within the Minister's letter that accompanied the formal direction it was confirmed that finance would be made available for the production of the feasibility study and for the implementation of the chosen scheme.

In addition to the above funding mechanisms, the Council will continue to work collaboratively with Welsh Government officers to identify all available and an appropriate funding mechanisms including transportation funds, to maximise the financial contribution from Welsh Government towards the implementation of any measures.

The proposed implementation costs of the preferred package is summarised as follows:

Measure	Est. Funding Requirements £M
Bus Retrofit	£2.25m
Taxi Mitigation Schemes	£1.86m
City Centre Schemes	£15.2m**
Active Travel 20 mph areas	£1.28m
Staff Resources	£0.395
Monitoring and Evaluation	£0.25m
	Total: **£21.2m**

Next Steps

This report will be reviewed and assessed by the Welsh Government's Expert Review Panel, prior to final approval of the preferred option being provided from Welsh Government.

Upon approval and confirmation of appropriate funding from Welsh Government, the Council will commence the implementation of the preferred option in line with the Implementation Plan detailed in the Management Case.

Section 1 Introduction

1.1 Cardiff

As the capital city of Wales, Cardiff has a population of 346,100 people, and is a base for many of the country's political, cultural, sporting and commercial institutions. Principal destinations include the Principality Stadium in the City Centre, the St David's shopping centres, and the historic Cardiff Castle. To the south of the city, Cardiff Bay (in the Butetown and Grangetown Wards) houses the Senedd, Wales Millennium Centre, BBC studios. Cardiff City Football Club and rugby union side Cardiff Blues are also both based in the capital.

Cardiff is located within a well-defined landscape setting with prominent ridges to the west and north and Severn Estuary to the south. The Western, Northern and Eastern areas of the City are mainly residential, with the main commercial areas being in the City Centre and to the south.
Cardiff is currently the most populated Welsh local authority, with approximately 361,468 inhabitants and this is predicted to grow to between 395,000 and 413,000 by 2026. Therefore, the Local Development Plan [1] calls for 41,100 new dwellings and 40,000 new jobs to be created. Such population growth is likely to place additional strain on the transport network, exacerbating existing problems of congestion and harmful emissions across the urban area.

In 2013, around 217,600 commuters travelled to work in Cardiff daily, with 83,100 commuting from outside of the city and 134,500 Cardiff residents travelling within the city to their place of work[2]. The city's travel to work area extends to the whole of South East Wales with an increasingly significant number of people arriving from Rhondda Cynon Taf, the Vale of Glamorgan and beyond.
Moreover, although there has been an increase in the use of active and sustainable modes of travel in recent years, the most used mode of travel in Cardiff both within and into the city is by the private car. The dominance of the private car leads to congestion and the associated adverse impacts on the environment, including air quality, greenhouse gas (GHG) emissions and noise pollution.
The countryside and urban area contains a wealth of natural and historic interests. For example, there are almost 1,000 Listed Buildings, 27 Conservation Areas, 2 sites noted for their international biodiversity (Cardiff Beechwoods SAC and Severn Estuary SAC/SPA/RAMSAR)
The city has a particularly rich Victorian and Edwardian legacy.
Cardiff has over 400 hectares of recreational open space and 2000 hectares of amenity space. The four river valleys of the Ely, Taff, Rhymney and Nant Fawr provide extensive and continuous blue corridors running from the countryside and through the urban area.

1.2 Overview of Study

The UK has in place legislation passed down from the European Union, to ensure that certain standards of air quality are met, by setting Limit Values on the concentrations of specific air pollutants. In common with many EU member states, the EU limit value for annual mean nitrogen dioxide is breached in the UK and there are on-going breaches of the nitrogen dioxide limit value in Cardiff. The UK and Welsh Government is taking steps to remedy this breach in as short a time as possible. Within this objective, the UK and devolved governments published a plan for tackling roadside nitrogen dioxide in July 2017. [3]

[1] Cardiff Council Adopted Local Development Plan 2006-2026
[2] Annual Population Survey 2014
[3] https://www.gov.uk/government/publications/air-quality-plan-for-nitrogen-dioxide-no2-in-uk-2017

Due to modelled air quality exceedances Cardiff Council has been directed [4] by the Minister to produce a feasibility study, to identify the option that will deliver compliance with legal limits for nitrogen dioxide in the area for which the authority is responsible, in the shortest possible time.

The Direction specified that Cardiff Council was required to produce an Initial Scoping Proposal, which required the Council to set out its proposed approach to the feasibility study and included a scope of work, governance, resourcing, procurement approach, indicative costs and timings. This report was required to be submitted, to Welsh Government no later than the 31st March 2018. Cardiff Council submitted this proposal to Welsh Government in March 2018[5].

The Direction subsequently requires two further aspects of the feasibility study. Firstly, an **Initial Plan,** setting out the case for change and identifying, exploring, analysing and developing options for measures, which the local authority will implement to deliver compliance in the shortest possible time, with indicative costs for those options. The Direction required this report be submitted to Welsh Government no later than the **30th September 2018.** This report was submitted to Welsh Government in line with the timelines of the direction.

This report sets out the Councils Final Plan setting out the preferred option to deliver compliance in the shortest possible time, including a Full Business Case (FBC) setting out value for money considerations and implementation arrangements and timings. This builds on the Interim Plan issued in March 2019. The Direction requires this report be submitted to Welsh Government no later than the **30th June 2019.**

The focus of the Feasibility Study is on achieving results in the shortest time possible.

1.3 Purpose of This Report

As detailed above this report presents the Councils Final Plan, setting out our preferred option which will bring about compliance with the Limit Value for annual mean NO_2 in the shortest time possible in Cardiff.

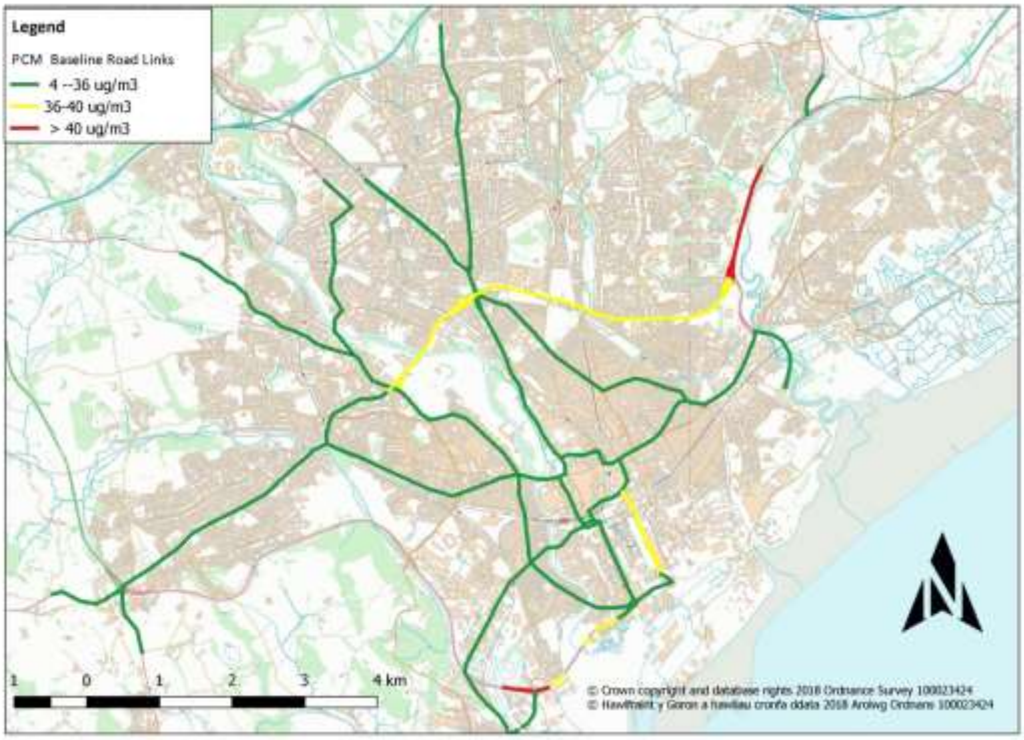
It has been produced where feasible in line with the Inception, Evidence and Options Appraisal packages of Guidance issued by the Joint Air Quality Unit (JAQU) in 2017, and the HM Treasury Green Book[6]. It also reflects the requirements of the Welsh Transport Appraisal Guidance (WelTAG).[7]

1.4 Summary of Initial Plan

The results of the local baseline modelling results are presented in detail in the Initial Plan Report[8] submitted to Welsh Government on the 30th September 2018. The results of the local modelling differed to that undertaken by Defra using the Pollution Climate Mapping model. DEFRAs modelling identified two road links under baseline conditions that were projected to show non-compliance beyond 2021 as detailed in Figure 1. The roads that were modelled as exceeding the NO_2 annual limit value for by 2021 using the DEFRA Model were the A48 and the A4232.

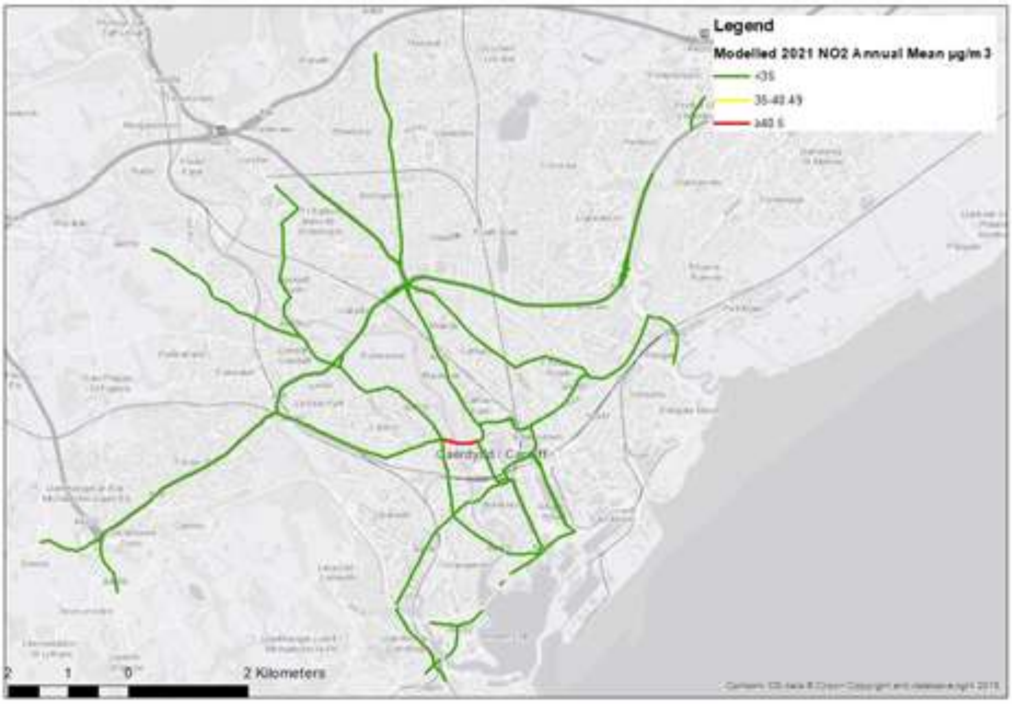
[4] Environment Act 1995 (Feasibility Study for Nitrogen Dioxide Compliance) Air Quality Direction 2018 14th Feb 2018
[5] Cardiff Council Initial Scoping Report for Feasibility Study
[6] HM Treasury Green Book
[7] https://beta.gov.wales/welsh-transport-appraisal-guidance-weltag
[8] Cardiff Council, Clean Air Feasibility Study – Initial Plan, September 2018.

Figure 1 - PCM Road Links Results 2021



The localised modelling as reported in the Initial Plan identified only one road link under baseline conditions projected to show non-compliance beyond 2021, this being the A4161 Castle Street as detailed in Figure 2.

Figure 2 - Local Modelling Baseline Results 2021



1.4.1 Target Determination

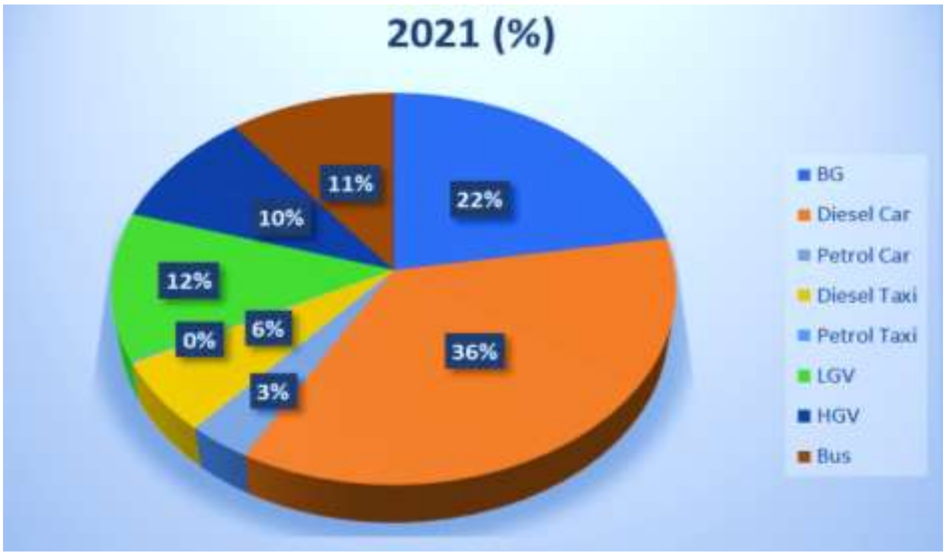
In assessing the model data, the main reason for this exceedance relates to very high traffic flows, some 32,000 vehicles a day and accompanying slow speeds of around 11mph on this specific road link.

The main reasons for the differences between the local model results and the PCM results is primarily down to the fact that the local model has a far greater level of detail which is based on local data, and not national assumptions, and thus can be seen to be a better representation of local circumstances. The key aspects of the local model that influence the results are as follows:

- Traffic flows are based on a local traffic model;
- Traffic speeds are based on a local model and local traffic master;
- Local fleet data from the ANPR, not just national averages; and
- Local topology is accounted for in terms of gradient, canyons,

In 2021 the main contribution to pollution on Castle Street, is anticipated to be road traffic (73 – 78 %), with diesel cars still contributing the largest proportion of emissions (36%) to the total road NOx emissions. The proportion of emissions from HGVs and buses is expected to reduce to 10% and 11% respectively. Figure 3 shows the source apportionment analysis on Castle Street for the baseline assessment for the forecasted year of 2021.

Figure 3 - Source Apportionment Analysis 2021



Within the Initial Plan Report a long list of measures were qualitatively assessed against a primary objective of **achieving compliance with set air quality objectives in the shortest possible time**. The measures were considered against secondary objectives and were subjected to further qualitative assessments against the WelTAG Well-being Aspects. As a result of this analysis the following shortlist of measures was decided upon and summarised in Table 1.

Table 1 - Initial Shortlist of Measures

Measure reference:	Scheme Description
M8	Implement further speed restrictions and enhance already established 20mph Zones.
M13	Development of Cycling Superhighways infrastructure and Expansion of Next bike Scheme
M14	Implement Zero Emission Buses on Cardiff Network
M21	Revision to Taxi Licensing Policy to include emissions standards
M11	Bus Network Programme- Strategic Bus Network to improve bus networks and efficiency of the services via increased and improved bus lanes
M12	Accelerate Park and Ride (P & R) programme in NW & NE of Cardiff. NW; Implement new Park and Ride facilities at Junction 33 (750 Spaces) and Llantrisant Road (250 Spaces). NE; expansion of P & R on the A48.
M10	City Centre West and Central Interchange and Eastside City Centre Schemes
M18	Improve and promote the uptake of low emission vehicles by enhancing Cardiff's EV infrastructure
M23	Review and implement car parking and car permit charges.

It must be noted that the above shortlist of measures were initially identified as measures that would likely have the greatest impact on the road links identified by the PCM modelling as being non-compliant, namely the A48 and A4232 near Cardiff Bay. However, the measures were also assessed in terms of their likely impact on improving air quality within the Councils existing Air Quality Management Areas (AQMAs). As detailed in the Initial Plan Report, the results of the local modelling demonstrated that compliance issues are not forecasted to occur on the A48 or the A4232. Non-compliance issues are now predicted to only occur on Castle Street which is immediately adjacent to the boundary of the City Centre AQMA, and measures put forward to address air quality in this AQMA will likely have an impact on this road link.

The above measures have been grouped together as a package of measures to assess their effectiveness in achieving compliance. In addition to the above measures, the Council as part of a benchmarking exercise to assessed the effectiveness of a Charging Clean Air Zone (CAZ) as a separate measure.

As detailed in the Initial Plan, the modelling of charging CAZ undertaken by Defra focussed on delivering compliance on the road links identified by the PCM model as being non-compliant. The local baseline modelling has demonstrated that non-compliance issues were not projected on the A48 or A4232 but where restricted to the City Centre with only Castle Street, A4161 projected to be non-compliant.

1.5 Summary of Interim Plan

The results of the Interim Plan – Outline Business Case (OBC)[9] were submitted to Welsh Government, following Cabinet approval in March 2019. This report presented the findings of local air quality and transport modelling of the shortlist of measures identified in the Initial Plan and these measures were also been benchmarked against a Charging Clean Air Zone.

The shortlist presented in the Initial Plan was as follows:

- Implement further speed restrictions and enhance already established 20mph Zones;
- Development of Cycling Superhighways infrastructure and Expansion of Next bike Scheme;

[9] Cardiff Council Interim Report - OBC March 2019

- Implement Zero Emission Buses on Cardiff Network;
- Revision to Taxi Licensing Policy to include emissions standards;
- Bus Network Programme- Strategic Bus Network to improve bus networks and efficiency of the services via increased and improved bus lanes;
- Accelerate Park and Ride (P & R) programme in NW & NE of Cardiff. NW; Implement new Park and Ride facilities at Junction 33 (750 Spaces) and Llantrisant Road (250 Spaces). NE; expansion of P & R on the A48;
- City Centre West and Central Interchange and Eastside City Centre Schemes;
- Improve and promote the uptake of low emission vehicles by enhancing Cardiff's EV infrastructure; and
- Review and implement car parking and car permit charges.

Prior to commencing the assessment of the above measures, further additional measures were also identified owing to the results of the local modelling. These additional measures have been assessed to include a wider Bus Retrofitting Programme, further network improvements on the A470 and a bus based P&R at Nantgarw.

In addition to assessing the package of measures, as required by the Government Guidance the Council assessed the effectiveness of a charging Clean Air Zone (CAZ) in terms of whether compliance could be achieved quicker than the proposed measures.

Government Guidance is clear that a charging CAZ should only be considered as a preferred option/ implemented if non-charging alternatives have been found to be insufficient to bring about compliance with air quality limits in the shortest possible time.

As a result the OBC has assessed two CAZ options for benchmarking purposes. Both options focussed on a small city centre zone. In summary the two CAZ options were assessed as follows:

- CAZ 1 – Private cars which did not meet Euro 4 (petrol) or Euro 6 (diesel) emission standards would be charged a £10 daily fee for entering the CAZ. No other vehicles were included in the CAZ.
- CAZ 2 – Commercial vehicles – HGVs, LGVs, did not meet Euro 4 (petrol) or Euro 6 (diesel) emission standards, would be charged daily rates for entering the CAZ. For HGVs the daily charge was set at £50 and for LGVs £10.

1.5.1 Result of Assessments

Localised air quality modelling and transport modelling was undertaken to establish the impact of the non charging measures and CAZ as to whether compliance could be achieved by 2021.

The CASAP measures were assessed accumulatively in terms of combining the measures identified in CASAP 1 with CASAP 2 and finally all measures have been assessed together as a final package, CASAP 3.

Unsurprisingly the full CASAP package demonstrated the greatest level of compliance on Castle Street, with 35 $\mu g/m^3$ forecasted as a result of the implementation of the measures. In addition to achieving compliance on Castle Street, the impact of the package of measures was also been modelled at local air quality monitoring locations, including those locations within existing Air Quality Management Areas (AQMAs). The results of the modelling indicated that all monitoring locations are expected to have concentrations below the 40 µg/m3 which further demonstrates that the package of measures will improve local air quality including within existing AQMAs.

As a comparison the results of the modelling undertaken on the CAZ scenarios are summarised as follows:

- **CAZ 1** – **Private cars** - achieves compliance on Castle Street – 32.5 μg/m^3;
- **CAZ 2** – **Commercial vehicles** – achieves compliance on Castle Street NO_2 – 35.3 μg/m^3

The results for CAZ 1 and 2 showed that NO_2 concentrations are estimated to be lower than the baseline 2021 scenario at most links, but with CAZ 1 showing small increases on 6 links and CAZ 2 showing increases on 4 links. The largest decrease observed in both CAZ 1 and CAZ 2 is on Castle Street, as might be expected for a measure that is specifically targeting the city centre. Compared to the CASAP measures**, most links showed higher concentrations of NO_2 in the CAZ 1 and 2 scenarios**.

UK Government guidance[10] is clear that a charging CAZ should only be considered as a preferred option if other non-charging measures are not sufficient to bring about compliance in the shortest possible time. In addition Welsh Government Policy[11] states that unless the Council can identify alternative measures to achieve compliance as quickly as a charging clean air zone then Welsh Government may direct the Council to introduce a charging clean air zone. The assessments undertaken to date demonstrates that non charging measures provide compliance in the same period, as Welsh Government have assessed that a CAZ could take up to 3 years to implement from the start of a feasibility study. The Councils study only commenced in March 2018, and thus the likelihood of a CAZ being implemented by 2021 is considered unlikely.

The modelling undertaken demonstrated that a package of measures achieves compliance in the same period if not sooner than a charging CAZ. Further as detailed above the implementation of the non-charging measures provides wider air quality improvements across Cardiff as a whole, including within the existing AQMAs.

Following a further qualitative assessment of the full CASAP measures a refined package of non-charging measures was concluded as being the Councils preferred option to take forwards to the Final Plan. This refined package of measures includes the following:

- Implementation of Electric Buses – 36 Electric Buses to be implemented on a number of routes within the City Centre;
- Bus Retro Fitting Programme –;
- Taxi Licensing Policy and Mitigation Scheme;
- City Centre Transportation Improvements ; and
- Active Travel Measures

The revised package of measures has now been assessed both in terms of transport and air quality modelling, as a final package of measures to enable the Council to develop the Full Business Case. **This report therefore provides the results of these assessments and has enabled the Council to decide on its preferred option, for the Final Plan.**

[10] Joint Air Quality Unit (JAQU) Evidence Based Approach to Setting Clean Air Zone Charges'
[11] https://gov.wales/sites/default/files/publications/2019-04/tackling-roadside-nitrogen-dioxide-concentrations-in-wales.pdf

Section 2 Strategic Case

2.1 Background and Strategic Context

The Initial Plan and Interim Plans presented a detailed baseline assessment of the existing situation, including an overview of legislation and policies and a description of the current EU Limit Value compliance status for Cardiff as well as a summary of the current local air quality management issues within Cardiff, and a summarised version is presented below.

2.1.1 UK Air Quality Strategy

The UK Air Quality Strategy[12] identifies nine ambient air pollutants that have the potential to cause harm to human health. These pollutants are associated with local air quality problems, with the exception of ozone, which is instead considered to be a regional problem.

The Air Quality (Wales) Regulations and subsequent amendments (National Assembly for Wales, 2000 and 2002) set objectives for the seven pollutants that are associated with local air quality. The objectives aim to reduce the health impacts of those pollutants to negligible levels as part of the Local Air Quality Management in Wales

Welsh Ministers have a responsibility to ensure air quality levels in Wales comply with air quality limit values in accordance with the Air Quality Standards (Wales) Regulations, 2010. Cardiff Council has a statutory duty under Part IV of the Environment Act 1995 & Air Quality Strategy for England, Scotland, Wales and Northern Ireland 2007 to manage local air quality. The Local Air Quality Management (LAQM) process places an obligation on all local authorities to regularly review and assess air quality in their areas, and to determine whether or not air quality objectives are likely to be achieved.

2.1.2 European Air Quality Directives

Air Quality Framework Directive (96/62/EC) on ambient air quality assessment and management defines the policy framework for 12 air pollutants known to have a harmful effect on human health and the environment. The limit values for the specific pollutants are set through a series of Daughter Directives. European Directive 2008/50/EC consolidates existing air quality legislation (apart from the 4th Daughter Directive) and provides a new regulatory framework for PM2.5.

The UK and Welsh Governments have an obligation to achieve European Air Quality Limit Values (Directive 2008/50/EC, Annex III). The most relevant are limits for nitrogen dioxide (NO_2) and Particulate Matter smaller than 10 µm (PM10) which must not exceed 40 µg/m3 as an annual mean (i.e. measured over a calendar year). There are a number of requirements of the Directive, including that the Limit Value applies at locations which are accessible, including footpaths but excluding areas within 25m from major road junctions.

In 2015, 37 of the 43 monitored areas across the country were in exceedance of the annual mean Limit Value for NO_2. One of these 43 areas includes the Cardiff Urban Agglomeration where the Government has forecast that exceedances will remain beyond 2021.

The Government assesses air quality compliance with the European Directive in 43 areas across the country at single locations, using both monitoring and modelling. It uses Defra's Pollution Climate Mapping (PCM) model to forecast exceedances, which is adjusted based on

[12] https://www.gov.uk/government/publications/the-air-quality-strategy-for-england-scotland-wales-and-northern-ireland-volume-1

the monitored data. This is the approved means of reporting air quality information to assess legal compliance with the European legislation.

2.1.3 Air Quality Objectives and Limit Values

The air quality objectives and limit values currently applicable to the UK can be split into two groups. UK air quality objectives set down in regulations for the purposes of local air quality management which are targets; and EU Limit Values transcribed into UK legislation which are mandatory.

A summary of the UK Air Quality Objective and EU Limit Values for NO_2 and particulate matter (PM10 and PM2.5) is given in Table 2.

Furthermore, the UK has a target to reduce average concentrations of PM2.5 at urban background concentrations by 2 µg/m3 by 2020.

Table 2 - UK and EU Air Quality Objectives for NO_2, PM10 and PM2.5

	Pollutant	Standard/ Concentration	Measured As	Date to be achieved and maintained thereafter
UK Air Quality Objectives	Nitrogen Dioxide	200 µg/m3 not to be exceeded more than 18 times per annum	1 Hour Mean	31.12.2005
		40 µg/m3	Annual Average	31.12.2005
	Particulate Matter (PM 10)	50 µg/m3 not to be exceeded more than 35 times per annum	24 Hour Mean	31.12.2004
		40 µg/m3	Annual Average	31.12.2004
	Particulate Matter (PM 2.5)	25 µg/m3	Annual Average	2020
EU Limit Values	Nitrogen Dioxide	200 µg/m3 not to be exceeded more than 18 times per annum	1 Hour Mean	01.01.2010
		40 µg/m3	Annual Average	
	Particulate Matter (PM 10)	50 µg/m3 not to be exceeded more than 35 times per annum	24 Hour Mean	01.01.2010
		40 µg/m3	Annual Average	01.01.2010
	Particulate Matter (PM 2.5)	25 µg/m3	Annual Average	2015

2.2 Public Health Impacts

There is clear scientific evidence which shows that air pollution exposure reduces life expectancy by increasing mortality and morbidity risk from heart disease, and strokes, respiratory diseases, lung cancer and other conditions[13]. Public Health Wales have stated that poor air quality is probably the second greatest health concern after smoking and is the most significant environmental determinant of health.

In the UK it has been estimated that an equivalent of **29,000** deaths are attributed to long term exposure to fine particulate air pollution exposure each year and an equivalent of **23,500** deaths are attributed to long term exposure to nitrogen dioxide (NO_2) exposure each year[14]. There is an overlap between the effects of both pollutants; as such, it has been estimated that the equivalent of **40,000 deaths** occur each year in the UK as a result of exposure to outdoor pollution[15]. On average, exposure reduces the life expectancy of every person in the UK by 7 to 8 months[16]. It has been estimated that reducing particulate air pollution by 10 µg/m3 in the UK would extend lifespan by five times more that eliminating casualties on the roads or three times more that eliminating passive smoking[17].

In Wales, based on data for the period 2011-2012, it has been estimated that an equivalent of **1,604** deaths can be attributed to fine particulate exposure each year, and **1,108** deaths can be attributed to nitrogen dioxide exposure each year[18]. Accounting for the pollutant effect overlap, it is estimated that an equivalent of around **2,000** deaths occur each year in Wales as a result of exposure to fine particulate and NO_2 exposure each year.

A study undertaken in 2014 published by Public Health England estimated that in **Cardiff 143** deaths were attributable to exposure to fine particulate air pollution.[19] More recent work by Public Health Wales estimates that the equivalent of over 220 deaths each year among people aged 30 and over in the Cardiff and Vale area that can be attributed to NO_2[20] with many more citizens suffering ill health as a consequence of poor air quality.

In 2012, the International Agency for Research on Cancer listed diesel exhaust pollution as a Class 1 carcinogen and extended this to all ambient air pollution in 2013.

For particulate air pollution and nitrogen dioxide there is no safe level of exposure and any initiatives to reduce air pollution will have positive health benefits. Welsh Government have indicated that the national air quality objectives used to identify Air Quality Management Areas (AQMAs) should not be seen as 'safe' levels and impacts are observed below levels permitted by current legal limits. Air pollution can cause adverse effects on health and quality of life at lower exposures, depending on the circumstances of the exposed individual. As a consequence, the majority of the avoidable health burden associated with air pollution in Wales is the result of population exposures outside AQMAs.

[13] WHO. Review of evidence on health aspects of air pollution-REVIHAAP. 2013. Copenhagen: WHO.
[14] Defra. Draft plans to improve air quality in the UK: tackling nitrogen dioxide in our towns and cities. UK overview document. 2015. London: Defra.
[15] Royal College of Physicians and Royal College of Paediatrics and Child Health (2016). Every breath we take: the lifelong impact of air pollution. From: https://www.rcplondon.ac.uk/projects/outputs/every-breath-we-take-lifelong-impact-air-pollution
[16] Defra. The air quality strategy for England, Scotland, Wales and Northern Ireland (vol. 1). 2007.
[17] Defra (2017) Air Quality: Public Health Directors briefing. From https://laqm.defra.gov.uk/assets/63091defraairqualityguide9web.pdf
[18] Brunt. H and McCarthy J., (2017). Estimating the mortality burden of air pollution in Wales
[19] Gowers. A. M, Miller., BG, Stedman., JR. Estimating local mortality burdens associated with particulate air pollution. 2014. London: Public Health England
[20] Estimating the mortality burden of air pollution in Wales, Public Health Wales

Although air pollution is a public health priority in Wales, its management needs to be a collaborative approach between public bodies, private companies, third sector partners and the public, all whom have important roles to play in addressing this pressing issue.
Poor air quality does not only have a significant health impact but it also has a wider societal cost. Accounting for health service costs and reduced productivity through lost work-days in the UK this is significant, standing at around £20b every year.[21]

Widespread air pollution is associated with routine car use for journeys within, into and out of, Cardiff. Well-designed measures to reduce air pollution will also increase active travel rates. Reducing reliance on the car as the primary mode of transport will have co-benefits of increased physical activity, mental well-being, and improved productivity and reduced stress, and will play a vital role in reducing carbon emissions which contribute to climate change.

The Director of Public Health's Annual Report 2017 highlights how our built environment has become increasingly shaped around car use over the last 50 years, with journeys made by car across the UK increasing from 27% to 83% over that period, while journeys made by bus have fallen from 42% to 5%, and by cycling from 11% to 1%. Over half of adults in our area are overweight or obese. To help reduce these levels, as well as levels of cardiovascular disease and type 2 diabetes, we need active travel to become the default for short journeys once again.

2.3 Air Quality in Cardiff

2.3.1 Monitoring

In 2017 there were 75 locations across Cardiff where monitoring for annual nitrogen dioxide (NO_2) concentrations is undertaken with the use of passive diffusion tubes. In addition, automated AURN monitoring stations are located on Frederick Street in the City Centre and Newport Road, which provide continuous monitoring for Nitrogen Dioxide (NO_2), Particulate Matter (PM_{10} & $PM_{2.5}$), Sulphur Dioxide (SO_2), Carbon Monoxide (CO) & Ozone (O_3).

2.3.2 Air Quality Management Areas

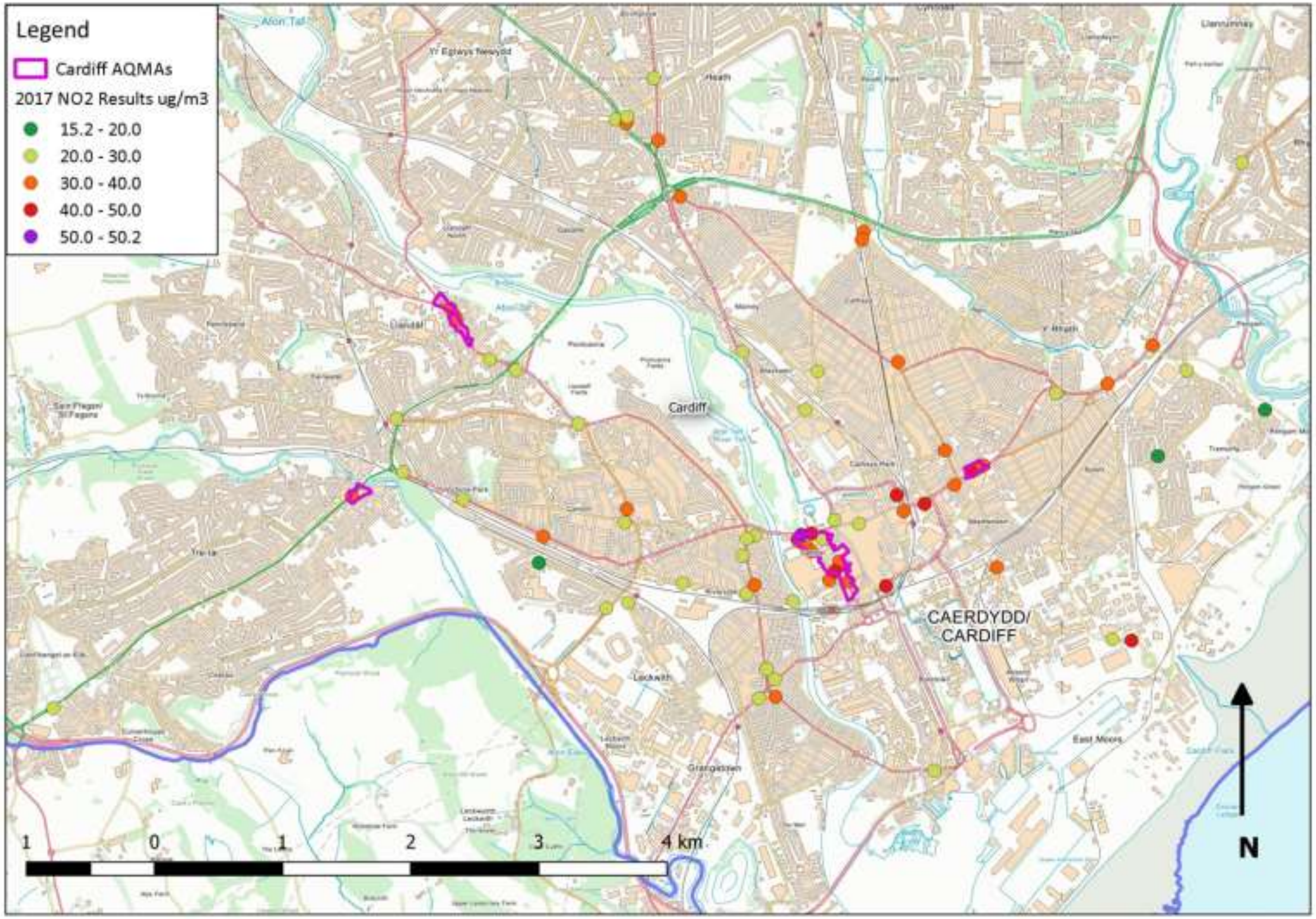
Based on monitoring results and further detailed assessments there are currently 4 Air Quality Management Areas (AQMAs) declared across the authority which were all declared due to exceedances of the annual mean NO_2 Air Quality Standard (40 $\mu g/m^3$), known to be derived from road transport.

Two AQMAs are primarily focused in Cardiff City Centre (Cardiff City Centre AQMA established: 01/04/2013 & Stephenson Court AQMA established: 01/12/2010).
North of the City Centre, lies the Llandaff AQMA established: 01/04/2013 and to the west of Cardiff is the Ely Bridge AQMA established: 01.02.2007.

Figure 4 details the location of the AQMAs and the results of the 2017 monitoring for NO_2 monitoring across Cardiff as reported in the Councils 2018 Annual Progress Report[22]. As yet the 2018 data has not been finalised and reported in the 2019 Annual Progress Report so these values have not been provided in this report.

[21] Royal College of Physicians and Royal College of Paediatrics and Child Health (2016). Every breath we take: the lifelong impact of air pollution.
[22] Cardiff Council 2018 Local Air Quality Management Annual Progress Report

Figure 4 – 2017 Monitored NO_2 Results and Existing AQMAs in Cardiff



2.3.3 Improvements to Air Quality -Progress to Date

The Council has a statutory requirement to produce an Air Quality Action Plan (AQAP) for each identified AQMA within the local authority area. However previous experience in implementing singular actions plans in Cardiff has not proven to be sufficiently successful. The main issue with this particular approach is that the AQAP focuses on introducing local measures to individual road links/ areas, which only targets at improving air quality within the identified AQMA itself.

Whilst such measures have been successful in improving air quality within the individual AQMA (High Street/ St Mary's Street Action Plan) such localised measures can ,and have led, to an adverse impacts on air quality in surrounding areas and result in more widespread air quality issues. These plans have not been sufficient enough in looking at the primary cause of the problem, this being road traffic derived emissions, resulting in air quality levels being detrimentally increased in neighbouring areas.

The Council recognise that there is no defined "safe level" when describing levels of NO_2[23]. The Council is committed to achieving NO_2 levels as low as reasonably practicable.
Datasets for annual average NO_2 levels recorded at relevant public exposure locations within the AQMAs do display signs of improvement. However, levels are consistently elevated and are seen to be either exceeding or encroaching on the annual average NO_2 objective. Table 3 draws upon ratified NO_2 datasets monitored via passive diffusion tubes at most relevant sensitive receptor locations, i.e., residential facades within each AQMA.

Table 3- Five Year Dataset For Monitored Annual Average NO_2 Levels At Residential Facades.

AQMA	Site ID	Bias Adjusted Annual Average NO_2 Concentration (µg/m^3)					
		2012	2013	2014	2015	2016	2017
City Centre	143	**41.5**	**42.1**	**42.1**	38.2	38.7	38.2
Stephenson Court	131	**47.9**	**43.9**	**41.2**	39.5	39.6	36.7
Ely Bridge	117	**42.6**	**44.9**	**42.3**	39.5	**41.3**	38
Llandaff	161	**43.0**	39.1	37.2	32.3	35.0	32.5

Bold -= exceedance of the Air Quality Standard for NO_2 as an annual average (40 µg/.m^3)

As displayed by Table 3, although it can be suggested that compliance is being met in the existing AQMAs, the Council do not consider these levels as low as reasonably practicable. With Cardiff's expected future growth and approved development works already in progress, further work is needed to ensure compliance with the air quality objectives and EU Limit Values is of a greater magnitude.

In order to monitor the Council's identified strategic measures and their effectiveness, the Council will continue to monitor levels of NO_2 at various relevant exposure locations citywide. The Council will look at improving the network of monitoring across the city by examining ways of increasing monitoring capabilities, for example looking at personal air quality monitoring for the public and purchasing automatic monitoring equipment to provide a further understanding of air quality trends. The Council will also design a transport monitoring programme which will look to examine different modes of transport trends, undertaken on a yearly basis. The scope for such a transport study would include examining figures for cycle trips, school journey mode determination, bus patronage, trends in peak traffic flow times

[23] Local air quality management in Wales Policy guidance June 2017

and fleet composition analysis using routes through AQMAs and surrounding tributary road networks.

2.4 Early Interventions

Since producing the Initial Plan the Council has made progress on a number of initiatives in Cardiff to promote and encourage modal shift to active travel and additional measures to increase the uptake of low emission vehicles (LEVs) which will ultimately lead to further improvements in air quality and these are summarised below. At this stage the impact that these measures have had on reducing NO_2 has not been quantified, and would be difficult to so. The main purpose of these measures is to provide further incentive to encourage the uptake of 0EV/ULEVs and increased active and public transport.

2.4.1 On Street Residential Charging Points

The Council has been successful in obtaining a bid from the Office of Low Emission Vehicles (OLEV) 36 charge points in 21 locations across the city and accessible to the public by 31st March 2019. The Council will aim to submit a further bid in 2019/20 to further increase the network of residential charging points.

In addition to the above the Council will also be launching a rapid charge pilot with a commercial provider to assess the viability of undertaking a wider implementation project.

2.4.2 Electric Charging Points at Council Facilities

The Council has made progress in terms of increasing electric charging infrastructure at four main employment hubs. It has been agreed that in 2019/20 for 8 electric vehicle chargers each at County Hall, Lamby Way, Wilcox House and Coleridge Road (i.e., total of 32 chargers).

In conjunction with this the proposals are in place for the Council to fund the hire lease costs of 56 new EVs in 2019/20 (replacing existing petrol/diesel vehicles) and 37 vehicles in 2020/21.

2.4.3 Planning Guidance for the Provision of Electric Vehicle Charging Points

In November 2018, the Council published a guidance documents for developers on the provision of charging points in new developments. This document sets out the Councils expectations on the minimum number of electric charging points that should be provided depending on the nature of the development. The expectations are summarised in Table 4 as follows:

Table 4 - Council Expectations on the Provision of EV Charging Points

Development Type	Provision
Houses	**One electric vehicle dedicated charging point** (up to 7kW (32A) where possible) **or installation of passive wiring** to allow future charging point connection per house with garage or driveway.
Flats	**At least 10% of parking bays** should be provide with dedicated electric vehicle weatherproof charging points.
Commercial Car Parks and Community Facilities	**At least 10% of parking bays** should be provided with dedicated electric vehicle weatherproof charging points.
Public Transport Facilities and Taxi Ranks	Charging infrastructure will be required to facilitate the conversion of bus and taxi fleet, using **appropriate technological solutions at suitable locations across the city.**
Future Proofing	Subject to agreement with the Local Planning Authority standard provision may also require **installation of groundwork/passive wiring at the outset** to enable further future installation to match demand.

2.4.4 Expansion of Nextbike Scheme

Since the introduction of the Nextbike scheme in March 2018, the Cardiff scheme has become the UKs most successful[24], with over 150,000 rentals since March 2018. As a result the scheme is set to double with an increase of a further 500 bikes bring the total number of bikes available to 1,000 bikes by the summer of 2019.

2.4.5 Public Service Board Targets

Working initially through Cardiff Public Services Board, a Healthy Travel Charter for Cardiff has been developed with major public sector employers and was launched in April 2019. Signatories to the Charter make 14 commitments on improving access to active and sustainable travel for staff and visitors to their main sites, and jointly commit to three targets namely:

- Reduce the proportion of commuting journeys made by car;
- Increase the proportion of staff cycling weekly; and
- Increase the proportion of vehicles used for business purposes which are plug-in hybrid or electric.

The Charter was signed by 11 public sector organisations at launch in April 2019, employing over 33,000 staff, with additional public and private sector organisations subsequently invited to sign up to the Charter.

Currently it is not possible to fully assess the impacts of the above the measures but it is envisaged that such measures will contribute to wider behavioural changes and incentives to encourage further modal shift or uptake of low emission vehicles which will see improvements in air quality.

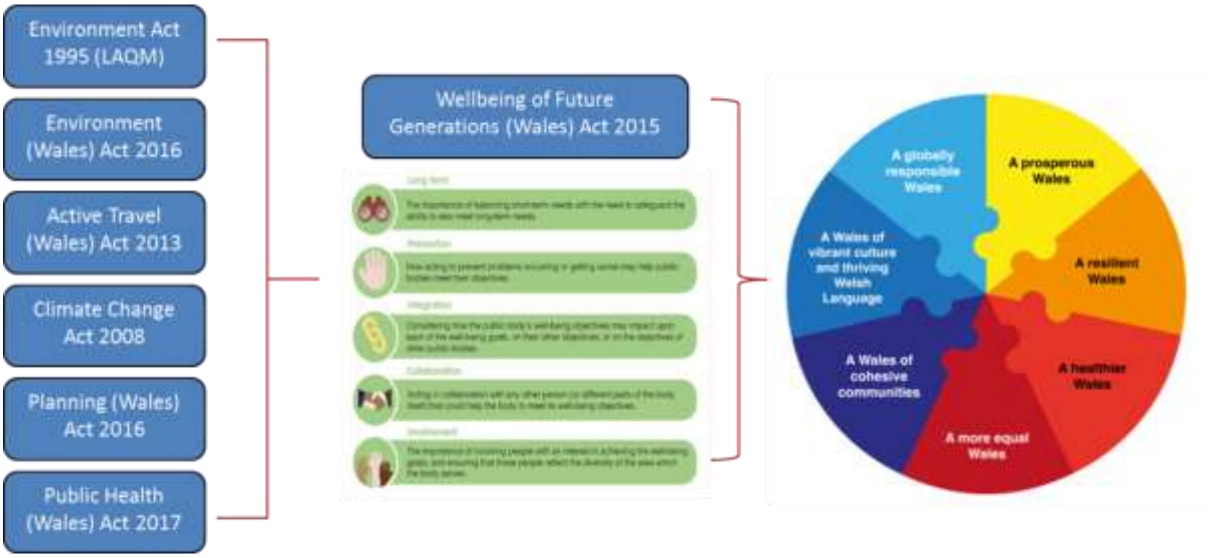
2.5 Well-being of Future Generations (Wales) Act 2015

The Well-being of Future Generations (Wales) Act 2015 (WFG) is a significant enabler to improve air quality as the Act calls for sustainable cross-sector action based on the principles of long-term, prevention-focused integration, collaboration and involvement. It intends to improve economic, social, environmental and cultural well-being in Wales to ensure the needs of the present are met without compromising the ability of future generations to meet their own needs. The Act places responsibilities on public bodies in Wales to work in new ways (including via Public Services Boards) towards national Well-being goals. Progress is measured against a suite of well-being and Public Health Outcomes Framework indicators; there is one specifically concerned with air pollution.

As Figure 5 illustrates, the Act is the legislative vehicle for "Health in all Policies in Wales" and provides the underpinning principles for all policy and decision making, including economic development, in Wales. Reducing air pollution, health risks and inequalities can help contribute to most, if not all, of the well-being goals. As such, the Act presents excellent opportunities to change policy and practice to enhance air quality management arrangements across Cardiff (and wider).

[24] NextBike In Depth Review 2018

Figure 5 - The Well- being of Future Generations (Wales) Act 2015 Matrix



2.5.1 Cardiff Well-Being Plan 2018-2023

Under the Act the Cardiff Public Services Board (PSB) has produced its Well-Being Plan for 2018-2023[25], which sets out the Cardiff PSB's priorities for action over the next 5 years, and beyond. The Plan contains Well-being Objectives, high-level priorities that the Cardiff PSB have identified as being most important. It also contains 'Commitments,' or practical steps that the city's public services, together, will deliver over the next 5 years. The Well-Being Plan has set out Well-Being Objectives as follows:

- **Objective 1** - A Capital City that Works for Wales;
- **Objective 2** - Cardiff grows in a resilient way;
- **Objective 3 -**Safe, Confident and Empowered Communities
- **Objective 4** - Cardiff is a great place to grow up;
- **Objective 5** - Supporting People out of poverty;
- **Objective 6** - Cardiff is a great place to grow older; and
- **Objective 7 -**Modernising and Integrating Our Public Services

Within the Well-Being Plan Objective 2 details the following; *Cardiff is one of Britain's fastest growing cities, and is by far the fastest growing local authority area in Wales. Successful cities are those in which people want to live and this growth is welcomed and a sure sign of strength for the city. However, this growth will bring challenges too, putting pressure on both the city's physical infrastructures, community cohesion, its natural environment and public services. Managing the impacts of this population growth and of climate change in a resilient and sustainable fashion will be a major long term challenge for Cardiff.*

Improving levels of NO_2 and particulate matter ($PM_{10,\ 2.5}$) is a City level outcome indicator that the PSB will seek to impact in order to meet this specific Objective. The Plan forecasts a future Cardiff with improved air quality and has committed to taking 'a *city-wide response to air pollution through supporting the development and delivery of a Cardiff Clean Air Strategy.'* Given the primary critical success factory of this feasibility study is achieve compliance with Limit Value for NO_2, it is fairly obviously that this study will fully compliment and assist the PSB

25 Cardiff Well-Being Plan 2018-2023

in achieving their Objective. The work to develop a Clean Air Strategy has been fundamental in developing this study, and enabled the development of a long list of measures that was assessed in the Initial Plan in terms of the measures meeting the primary success factory. The Clean Air Strategy is included in Appendix C.

2.5.2 National Well-Being Goals and the Five Ways of Working

The feasibility study will ensure that future decision making in terms of air quality will comply with the WFG in terms of ensuring that meets the five ways of working as set out below. The following assessment has considered how the package of measures meets the five ways of working and has followed https://futuregenerations.wales/documents/future-generations-framework/

Long term – The feasibility study aims to balance short-term needs of achieving compliance with the limit value in the shortest possible time, with the need to ensure longer term continued improvement in air quality within Cardiff. Whilst the measures assessed later in this report provide potential solutions to the identified compliance issues, the Council has longer term ambitions to improve air quality in Cardiff beyond legal limits, in order to reduce public exposure to as low as reasonable practical. This is demonstrated in the full Clean Air Strategy as detailed in Appendix C which sets out further measures that are not intended to achieve compliance in the shortest possible time, but provide further initiatives to ensure that once compliance is achieved the focus of the Council is to provide wider improvements in air quality thus fulfilling one of the aims for Objective 2 of the Well-Being Plan for Cardiff.

Prevention –By implementing the preferred option identified by this study, the Council will ensure improvements in air quality are achieved, as demonstrated by the modelling work reported in Section **Error! Reference source not found.**. This will ensure that preventative action is taken by the Council to address the air quality issues in terms of not only achieving compliance in the shortest possible time, but implementing wider measures as detailed in the Clean Air Strategy and Action Plan to prevent air quality getting worse in the future, thus protecting public health and the wider environment.

Integration–The development of a preferred option in the Final Plan will take into consideration other public body's well-being objectives and will assess how the preferred option may impact upon each of the well-being goals, or on the objectives of other public bodies. The Council has worked with the PSB in developing this study and has ensured the PSB has been fully informed on the development of the study.

Collaboration –The development of the preferred option detailed within this report has been done so in collaboration with many departments within the Council and other external organisations, e.g., Public Health Wales, local bus operators.

Involvement –Prior to developing the Final Plan the preferred option as set out by this report, will be subject to an appropriate level of public engagement interest groups have an opportunity be fully involved and their opinions on the preferred option considered as the Council develops our Full Business Case to be presented in the Final Plan.

Overall, improving air quality and developing a preferred option to achieve compliance with the NO_2 limit value, contributes significantly to the majority of the well-being goals, but specifically as follows:

A Globally Responsible Wales – Poor air quality is recognised globally as a major health and environmental issue that needs urgent action. The development of a preferred option and its subsequent implementation will see Cardiff Council work towards improving air quality and leading the way for Wales.

A Healthier Wales – As detailed in Section 2.2 air quality is now considered the greatest environmental risk to health with proven detrimental impacts on human health. The development and implementation of our preferred option will ultimately improve the air quality within Cardiff, which will provide overall public health benefits. The inclusion of measures to increase active travel and behavioural change will lead to a more active and healthier population in Cardiff, and cleaner air will ultimately encourage further uptake of active travel.

A Prosperous Wales – As detailed in Section 2.2 the impact of poor air quality has a secondary impact on productivity due to days lost and thus an impacts on the health service costs. The implementation of the preferred option to address the compliance issues and to improve air quality will have additional benefits in terms of productivity and a reduction in health service costs.

A further qualitative assessment of how the preferred option contributes positively or negatively to the well-being goals is provided in the summary appraisal tables as detailed in Section 3.8.2.

2.6 Consistency and Relevance with Other Policies

2.6.1 Local Policy

2.6.1.1 Local Transport Plan

Cardiff Council's longstanding vision for transport in the city is for:

"An integrated transport system that offers safe, efficient and sustainable travel for all, where public transport, walking and cycling provide real and desirable alternatives to car travel, which contributes to making Cardiff Europe's most liveable capital city."

Our priorities to achieve this are:

1. Widening travel choices making it practical for most daily trips to be made by alternatives to the car, such as public transport, walking and cycling;
2. Demand management taking steps to reduce the demand for travel overall, and particularly by car ; and
3. Network management using technology to make best use of the existing highway network, rather than building new roads that would generate more traffic.

As a result, it is necessary to assess how the various options considered to improve the air quality in Cardiff will align with, and support, the realisation of the strategic objectives contained within the emerging policy documents.

The key strategic themes and principles of the existing policies overlap with several of the critical success factors used in the economic assessment, including those related to air quality improvements, benefits to the economy, social inclusion and public health benefits.

Cardiff is growing and changing, and this brings more journeys and more pressures on Cardiff's transport network. Reducing the number of car journeys made in the city, and promoting the use of active and sustainable modes of travel, is central to Cardiff Council's Transport Strategy and in improving air quality in the city. Our Local Development Plan (LDP) provides for 41,000 new homes and up to 40,000 new jobs up to 2026. The LDP sets the target of achieving a 50:50 modal split – this means that 50% of all journeys need to be made by sustainable transport by 2026 in order to accommodate the future development set out in the LDP. Our policies set out in the LDP support the need to secure significant improvements to the public transport and active travel networks in combination with new developments.

Cardiff's Local Transport Plan (LTP) was approved by the Welsh Government in May 2015. The LTP sets out our main transport infrastructure proposals which will support this significant modal shift. The Local Transport Plan recognises the need to improve air quality and in doing so its programme prioritises:

- Development of active travel networks to increase walking and cycling for local journeys;
- The provision of cycling infrastructure;
- The bus network;
- Reduced speed limits;
- Reducing congestion;
- Improving transport efficiency and reliability; and
- Bus based park and ride

The LTP has been used to help develop a number of the measures which have been assessed by this study.

2.6.1.2 Cardiff's Local Development Plan 2006-2026

Cardiff's Local Development Plan (LDP) 2006-2026, forms the basis for decisions on land use planning in Cardiff up to 2026 and assumes that, within the plan's time frame, approximately 40,000 new jobs and 41,100 new dwellings will be developed in Cardiff as a direct response to Cardiff's role as the economic driver of the City-region.
In addition to its independent examination, the LDP was subject to a Strategic Environmental Assessment (SEA) to ensure that the policies reflect sustainability principles and take into account environmental impacts.

Policy KP2 of the LDP allocates 8 Strategic Sites to help meet the need for new dwellings and jobs. These strategic allocations on both Greenfield and brownfield sites will include 500 homes or more and/or include significant employment/mixed uses which will bring significant benefits to the city. The sites are:

(i) Cardiff Central Enterprise Zone;
(ii) Former Gas Works, Ferry Road;
(iii) North West Cardiff;
(iv) North of Junction 33 on the M4;
(v) South of Creigiau;
(vi) North East Cardiff (West of Pontprennau);

(vii) East of Pontprennau Link Road; and
(viii) South of St. Mellons Business Park – Employment Only.

The LDP identifies that sustainable transportation solutions are required in order to respond to the challenges associated with new development by setting out an approach aimed at minimising car travel, maximising access by sustainable transportation and improving connectivity between Cardiff and the wider region.

The Plan sets out a strategy to achieve this by making the best use of the current network, managing demand and reducing it where possible by widening travel choices. The aim is to secure a modal split of 50% car and 50% non-car modes.

The following LDP policies are of relevance to air quality;

KP8: SUSTAINABLE TRANSPORT
Development in Cardiff will be integrated with transport infrastructure and services in order to:
i. Achieve the target of a 50:50 modal split between journeys by car and journeys by walking, cycling and public transport;
ii. Reduce travel demand and dependence on the car;
iii. Enable and maximise use of sustainable and active modes of transport;
iv. Integrate travel modes;
v. Provide for people with particular access and mobility requirements;
vi. Improve safety for all travellers;
vii. Maintain and improve the efficiency and reliability of the transport network;
viii. Support the movement of freight by rail or water; and
ix. Manage freight movements by road and minimise their impacts

For Cardiff to accommodate the planned levels of growth, existing and future residents will need to be far less reliant on the private car. Therefore, ensuring that more everyday journeys are undertaken by sustainable modes of transport, walking, cycling and public transport, will be essential.

KP14: HEALTHY LIVING
Cardiff will be made a healthier place to live by seeking to reduce health inequalities through encouraging healthy lifestyles, addressing the social determinants of health and providing accessible health care facilities. This will be achieved by supporting developments which provide for active travel, accessible and useable green spaces, including allotments.

KP18: NATURAL RESOURCES:
In the interests of the long-term sustainable development of Cardiff, development proposals must take full account of the need to minimise impacts on the city's natural resources and minimise pollution, in particular the following elements......minimising air pollution from industrial, domestic and road transportation sources and managing air quality.

EN13: AIR, NOISE, LIGHT POLLUTION AND LAND CONTAMINATION
Development will not be permitted where it would cause or result in unacceptable harm to health, local amenity, the character and quality of the countryside, or interests of nature conservation, landscape or built heritage importance because of air, noise, light pollution or the presence of unacceptable levels of land contamination.

C6: HEALTH
Priority in new developments will be given to reducing health inequalities and encouraging healthy lifestyles through:
i. Identifying sites for new health facilities, reflecting the spatial distribution of need, ensuring they are accessible and have the potential to be shared by different service providers; and
ii. Ensuring that they provide a physical and built environment that supports interconnectivity, active travel choices, promotes healthy lifestyles and enhances road safety.

The LDP also outlines the approach the Council will take to increase the proportion of people travelling by sustainable modes and to achieve the 50:50 modal split target. This will involve:

- enabling people to access employment, essential services and community facilities by walking and cycling through, for example, high quality, sustainable design and measures to minimise vehicle speed and give priority to pedestrians and cyclists;
- developing strategic bus and rapid transit corridor enhancements and facilitating their integration with the wider transport network;
- facilitating the transfer between transport modes by, for example, improving existing interchanges and developing new facilities such as strategically located park and ride facilities; and
- maximising provision for sustainable travel within new developments and securing infrastructure investment which can support modal shift within existing settlements.

2.6.1.3 Capital City Regional Deal

The Cardiff Capital Region (CCR) City Deal is a programme agreed in 2016 between the UK Government, the Welsh Government and the ten local authorities in South East Wales to bring about significant economic growth in the region through investment, upskilling, and improved physical and digital connectivity.
One of the Cardiff Capital Region (CCR)'s objectives is to connect communities, business, jobs, facilities and services in the area. The CCR Transport Authority, working closely with the Welsh Government, Transport for Wales and others, has been established as a sub-committee by the CCR Cabinet to facilitate the City Deal by coordinating transport planning and investment across the region. The transport improvements underlying the CASAP measures to be assessed later in this report will be fundamental to delivering this objective of CCR.

2.6.2 National Policy

There are a number of key Welsh Government Policy strands that our feasibility study directly relate to and compliment and thus the outcomes of this study should act as a catalyst to achieving a number of these policies.

2.6.2.1 Prosperity for All

In September 2017, the Welsh Government published a national strategy, Prosperity for All[26] to deliver its key priorities during the latest term of the Assembly. One of the key themes of this strategy is to build healthier communities and better environments, and a key aspect of this theme is to reduce emissions in order to deliver improvements to air quality. The Councils Feasibility Study and identification of a preferred option to deliver legal compliance will work towards this building healthier communities and better environments by ensuring compliance with the Ambient Air Quality Directive is achieved in the shortest possible time.

[26] Welsh Government, 2017 – Prosperity for All

2.6.2.2 Welsh Transport Policy

A revised Wales Transport Strategy is due to be published by the end of the 2019, and it is understood that Improving air quality by reducing emissions will be key pillar within this strategy. The revised package of CASAP measures which will be assessed in detail later in this report aim to reduce emissions, through vehicle upgrades/ retro fitting existing bus fleets, and increasing the uptake of active travel. The implementation of a preferred package of measures which priorities such measures will ensure consistency with any future Welsh Transport Policy.

2.6.2.3 Planning Policy Wales

Welsh Government have stated in the most recent Planning Policy Wales (PPW)[27] that it is s committed to reducing reliance on the private car and supporting a modal shift to walking, cycling and public transport. Delivering this objective will make an important contribution to decarbonisation, ***improving air quality***, increasing physical activity, improving the health of the nation and realising the goals of the Well-being of Future Generations Act.

PPW further states that Air just barely compliant with these objectives is not 'clean' and still carries long-term population health risks, and thus it is desirable to keep levels of pollution as low as possible.

The Councils feasibility study, therefore fully compliments PPW in terms of implementing measures that look to reduce the reliance on the private car and increasing modal to active and public transport. Such measures will be assessed in terms of not only achieving compliance but reducing levels of NO_2 to as low as reasonable practical.

2.6.2.4 Active Travel (Wales) Act 2013

This Act[28] came into force in September 2014 and requires local authorities to map and continuously improve routes and facilities for cycling and walking. Reducing road traffic emissions will be a key aspect of the measures being taken forward and thus the increase in modal shift to active travel will be a key component of the Councils preferred option to achieve compliance. The increase in active travel will be assessed as part of the CASAP measures.

2.7 Stakeholder Engagement

In order to ensure that Cardiff Council implements a solution that not only delivers compliance in the shortest possible time, but ensures that such a solution is supported and welcomed by citizens, businesses and visitors to Cardiff it will be vitally important to fully engage and work with the public and businesses to ensure that the preferred option implemented meets the citizens expectations.

2.7.1 Consultation on the Preferred Option

Cardiff Council's Clean Air Project Team strategized and developed a consultation and engagement exercise to provide an opportunity for Cardiff's citizens to review and comment on the proposals developed to address Cardiff's air quality concerns localised to Castle Street.

The Council undertook a 6-week public consultation between 3rd April 2019 and 15th May 2019. Via Cardiff Council's website detailed information surrounding the proposed package of mitigation measures was made available to members of the public. The website also linked to an online survey developed by Cardiff's Clean Air Project Team, providing background information on the individual measures and a questionnaire to be completed. The online

[27] Planning Policy Wales – 10th Edition December 2018
[28] Active Travel (Wales) Act 2013

survey provided a platform for participants to make additional comments and contact the Clean Air Project Team with any related air quality concerns.

Supporting the consultation, Cardiff's Clean Air Project Team accommodated four public engagement events which allowed members of the public to ask further details about the package of measures. The engagement sessions were held on/ at;

- April 13th: Angel Hotel
- April 20th: Central Library
- May 4th: Angel Hotel
- May 11th: Central Library

Further notification of the consultation and engagement exercise was distributed to members of the Council's Citizens' Panel, consisting of over 5,000 residents across the city, as well as a list of key stakeholders. In addition social media, was used during the consultation, to promote the events and each week a different measure was focussed upon for 'tweets' and updates.

The main principles and objectives for the consultation and engagement exercise was to:

- Show transparency and communicate clearly to residents and stakeholders the proposals for a package of non-charging mitigation measures in Cardiff;

- Ensure any resident, business or stakeholder who wishes to comment of the proposals has the opportunity to do so, enabling them to raise any impacts the proposals may have so that these could be taken;

- Allow participants to propose alternative suggestions for consideration which they feel could achieve the objective in a different way;

- Provide feedback on the results of the consultation to elected Members to enable them to make informed decisions about how to best progress; and

- Ensure that the results are analysed in a meaningful, timely fashion, so that feedback is taken into account when decisions are made before finalising the Full Business Case (FBC).

Overall, there were 1,303 responses received for the consultation. The results of the Consultation responses are summarised below and with the full Consultation Response Report presented in Appendix E.

The preferred option of non-charging measures received overwhelming support, particularly the measures targeted at improving emissions from buses and taxis.

- **96.8%** support the proposal to replace the most polluting diesel buses with electric buses;
- **90.4%** support the proposal to retrofit other polluting buses so they are upgraded to meet the latest emission standards; and
- **80.3%** support the proposed changes to taxi licensing in the city

Considering that it was only possible to include the high level design principles of the City Centre Schemes within this consultation, the proposals were favourably received with **two-thirds of respondents supporting the proposals, with just under a fifth against.**

82.8% of the respondents to the survey were car owner/ drivers, and 15.6% identified themselves as not a driver.

2.8 Case for Change

2.8.1 Primary Objective

The primary objective of the feasibility study and spending objective is to deliver a scheme that leads to compliance with the EU AAQD annual average NO_2 limit value in the shortest possible time and thus to identify a preferred option to achieve this.

2.8.2 Secondary Objectives

JAQU's Options Appraisal Package [29]document states that while the primary CSF allows appraisers to test whether an option meets the minimum requirements, other secondary CSFs are needed to undertake a comparative assessment of the options. The guidance states that these may include factors such as value for money, distributional impacts, wider strategic air quality policy alignment, affordability and achievability.

Following this guidance, a number of secondary CSFs have been defined for the Plan for which options that have been assessed as achieving the Primary CSF have been further assessed against. Further, this study contributes to the strategic priorities for Cardiff Council, including that of the Well-being of Future Generations (Wales) Act 2015. As such, based on the Future Generations Act and the further recommendations within The National Institute for Health and Care Excellence (NICE)[30] on air quality guidelines and health, the following are considered as **secondary objectives** in the appraisal process:

- Will the measure deliver an overall reduction in NO_2 emissions to air;
- Will the measure result in additional benefits or other environmental improvements;
- Will the measure contribute to well-being goals:
  - Will the measure have a positive impact on wider public health;
  - Mitigate financial impact on low income households and reduce inequalities;
- Does the option fit or compliment other local policies;
- Value for Money - Do the likely benefits of this option exceed the costs; and
- Are there constraints that prevent/ impact on the implementation of the measure?

2.9 Key Constraints, Risks and Benefits

2.9.1 Constraints

In reviewing the information the key constraints of the final plan and preferred option of a package of measures are as follows: The key constraints are:

- Ensuring compliance of the EU AAQD for nitrogen dioxide annual mean within the shortest possible time (Primary objective).
- Procurement and delivery timescales for the City Centre Schemes;
- Ensuring wider air quality improvements in terms of NO_2 and $PM_{2.5}$ are achieved (key secondary objective)
- To ensure the plan is proportionate in achieving the primary objective.

[29] Joint Air Quality Unit - OPTIONS APPRAISAL GUIDANCE 2017
[30] NICE (2017). Air pollution: outdoor air quality and health. NICE Guideline NG70

2.9.2 Risks and Mitigations

The key risks to the delivery of the plan are detailed below in Table 5 and scheme specific risks are identified in the management case and full risk register.

Table 5 - Key Risks and Mitigations for Project

Risk	Impact	Mitigation
Compliance is not achieved in the shortest possible time	High	Robust technical assessment provides confidence that compliance will be achieved. By implementing the preferred option, achieving the primary objective is more likely, >90%. A monitoring and evaluation programme will measure the impact of the schemes and mitigating action will be taken where necessary.
Minister does not approve Final Plan	Medium	In developing the Final Plan the Council has worked closely with the Air Quality Branch in Welsh Government to ensure that the plan produced meets the primary objective of achieving compliance in the shortest possible time.
Full Funding for the Plan is not awarded	Medium	The Council has ensured that the financial case is robust and the preferred option is considered to provide to optimum benefit in terms of achieving the primary and secondary objectives. The Council has identified existing funding measures and also considering further commercial loan to Cardiff Bus to ensure the DfT grant can be complied with to enable Electric Buses to be procured.
Measures are not supported by stakeholders	Low	The Council undertook a public consultation on the preferred option and overwhelming support for the majority of the measures has been received. The City Centre Transport Improvement Schemes will be subject to further statutory consultation to finalise the detailed designs prior to the implementation of the works. Continued engagement on the Clean Air Cardiff Project will continued using existing the stakeholder database to ensure key stakeholders are full engaged through the implementation phases.

2.9.3 Benefits

They key benefits by implementing this plan are as follows:

- Compliance with the EU AAQD within the shortest possible time is achieved;
- Public health benefits are delivered by improved air quality;
- Measures promote ongoing improvements in public health and air quality;
- Increase use in sustainable and active travel modes of transport, reduction of accidents and increased road safety in the City Centre.

These benefits will be assessed as part of the monitoring and evaluation programme and benefits realisation, benefits are discussed further in the management case.

Section 3 Economic Case

3.1 Introduction

The Interim Plan, OBC identified a refined package of non-charging measures that would be taken forward as the Councils preferred option. These measures were identified as measures that could be implemented in the shortest possible time, and would likely lead to a reduction of human exposure whilst the full plan is implemented to achieve compliance. For reference the preferred option is detailed in Table 6 as follows;

Table 6 - Shortlist of Measures Detailed in Initial Plan

	Scheme Description
Electric Buses	36 Electric Buses to be implemented on a number of routes within the City Centre;
Bus Retro Fitting Programme	Retrofit of remaining non-Euro 6 buses to Euro 6, to complement the electric buses measure above.
Taxi Licensing Policy	Revision of taxi licensing policy to only allow any new grants or change of vehicles to be less than 5 years old and minimum Euro 6 emission standard. Also revision of exceptional condition that the maximum age that a vehicle can be licensed is 10
City Centre Transportation Improvements	City Centre Improvements including City Centre West Transport Improvement Scheme, Part of East side city centre scheme (Station Terrace) and the Castle Street scheme.
Active Travel Improvements	Expansion of 20 mph areas, and completion of CS1

Cabinet approved the above the package be taken forward as the preferred option and that the in order for the study to provide a robust assessment of the impacts of these measures, that they be modelled as a package of measures rather than individual measures. The rest of this section provides the methodology and results of the transportation and air quality modelling results of the preferred option. In order to provide comparison the modelled results of the Clean Air Zone (CAZ) 1 scenario presented in the Interim Plan are also provided in this report.

3.2 Modelling of the Preferred Option

The section outlines the transport modelling work undertaken by Mott MacDonald to assess the transportation impacts of the preferred option to develop the evidence base to progress this study. Transport modelling has been undertaken using the South East Wales Transport Model (SEWTM) using methods that are appropriate for a high-level feasibility study. The full details of the transport modelling are included in Appendix B of this Report.

3.2.1 Preferred Option Modelling

The revised package of non-charging measures detailed in the Interim Plan have been assessed in the transportation and air quality models using the 2021 baseline as a starting point. The same modelling has been undertaken to assess the revised package of non-charging measures for the Final Plan. The details of the full air quality and transportation modelling methodologies are detailed in Appendix A and Appendix B.

Table 7 – Preferred Option Modelling Assumptions

Measure	Modelling assumptions
Active travel package	20mph zones and cycle scheme CS1 (Heath to City centre corridor) measures rolled out in two areas of the city, which assume a 3.5% reduction in car driver mode share and applied in the transport model.
ULEB application for 36 electric buses	The 36 zero emission buses were allocated to routes 27, 49/50, 44/45, with the related bus AADT removed as these are now zero emission. The remaining bus fleet is then adjusted to reflect the removal of 36 older Euro3 vehicles.
CBTF retro-fit programme	Assumed 80% uptake of retrofit of remaining non-Euro 6 buses to Euro 6, to complement the electric buses measure above.
Taxi licensing	Sets a 10 year age limit and all renewals to be Euro 6 from 2019. Plus a grant scheme for taxi drivers, when renewing to Euro 6, to buy plugin hybrids or fully electric vehicles. Taxi fleet adjusted to remove all vehicles over 10 years old and replace these by new Euro 6 vehicles. Assumed that this results in a 15.8% shift from non-compliant to compliant private hire vehicles (of which, 7% assumed to upgrade to an electric vehicle), and a 45.5% shift for hackney carriages (of which, 4% assumed to upgrade to an electric vehicle).
City Centre transport schemes, including City Centre West Transport Improvement Scheme, Part of East side city centre scheme (Station Terrace) and the Castle Street scheme.	City Centre West Transport Improvement Scheme modelled through movements prevented from using Westgate Street and applied in the transport model. East side city centre scheme modelled through movement prevented on Churchill Way, except for buses, and applied in transport model. Castle street scheme modelled with removal of vehicle lane and replacement with a cycle lane. Westgate and East side measures now assume exceptions for taxis (not included in CASAP 1-3 modelling)

3.3 Modelled Results of Preferred Option on PCM Road Links

In line with the modelled results for the baseline, CASAP 1-3 and CAZ scenarios, the results for the preferred CASAP scenario have been generated for each of the PCM road links. This has been done in exactly the same way as the previous air quality modelling. A full list of tabulated results for the PCM road links for the modelled years of 2015 and 2021 is shown in **Table 8**. Mapped results from the local modelling study on PCM links are shown in Figure 6.

Table 8 - PCM and local model NO_2 $\mu g/m^3$ concentration results for Baselines 2015/2021 and Preferred Option

Road	PCM Baseline		Local Baseline		Preferred Option
	2015	2021	2015	2021	2021
A4119	22.4	17.9	*37.1*	*30.7*	*30.1*
A4054	19.1	15.0	*25.3*	*19.5*	*17.7*
A4119	29.9	24.0	*34.4*	*24.4*	*22.2*
A4161	40.3	32.7	*34.9*	*26.2*	*25.4*
A48	27.9	22.3	*32.9*	*25.4*	*24.4*
A4119	27.2	21.8	*23.8*	*18.8*	*17.6*
A470	31.1	25.2	*45.4*	*30.6*	*24.1*
A4160	32.2	25.7	*36.7*	*26.9*	*26.1*
A4161	43.7	33.8	*42.2*	*30.8*	*25.4*

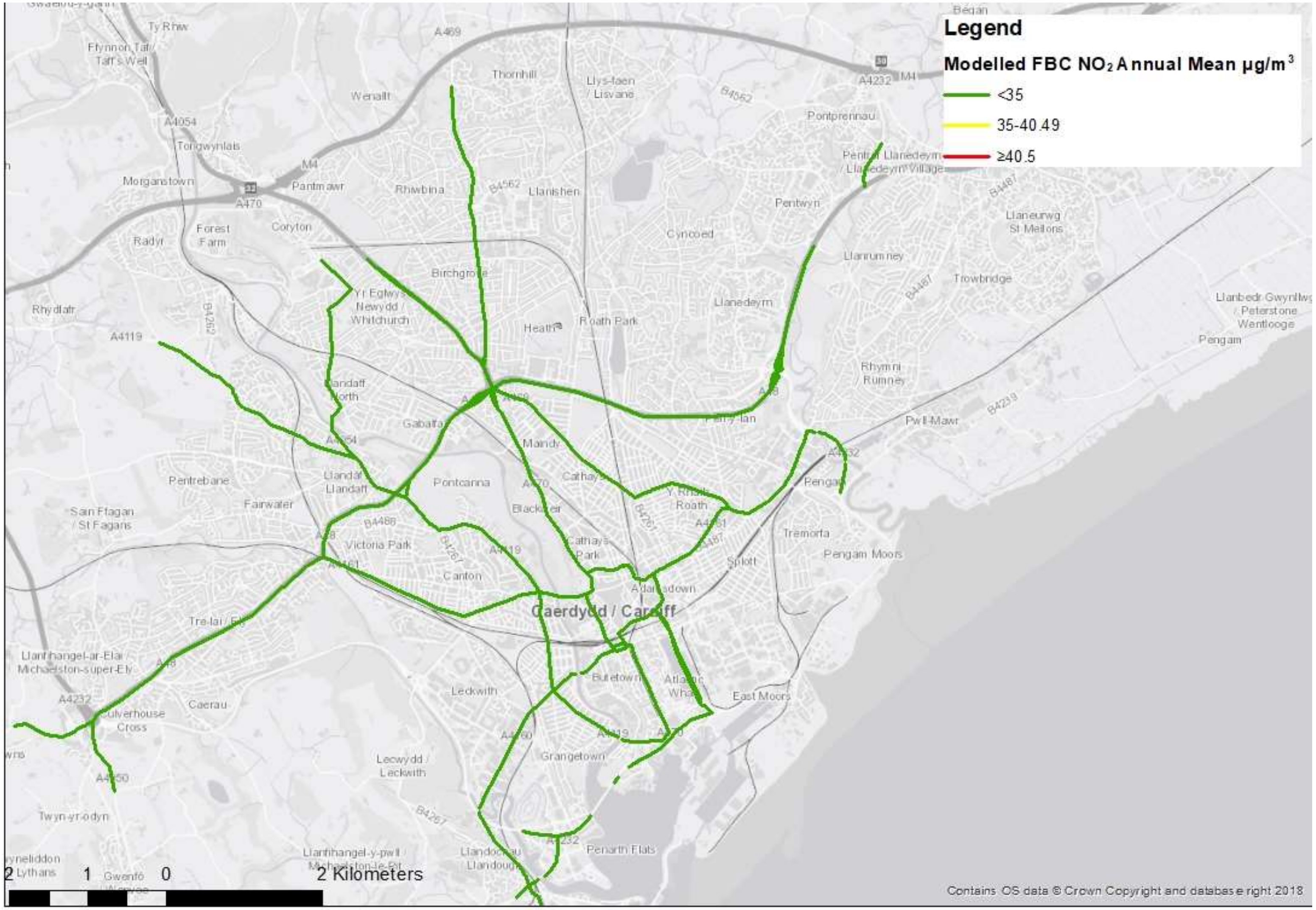
Road	PCM Baseline		Local Baseline		Preferred Option
	2015	2021	2015	2021	2021
A4161	37.5	29.7	*43.9*	*30.4*	*26.6*
A469	33.1	27.1	*27.2*	*21.5*	*20.0*
A4160	30.4	25.0	*30.4*	*23.7*	*21.4*
A4119	31.9	25.9	*36.6*	*29.0*	*26.3*
A4232	47.3	37.7	*34.3*	*29.5*	*28.6*
A48	48.8	39.1	*40.0*	*30.6*	*31.4*
A4160	28.2	22.7	*24.2*	*19.3*	*17.7*
A469	28.5	22.4	*33.0*	*25.8*	*24.2*
A4161	29.5	23.3	*26.5*	*20.3*	*19.0*
A4161	24.9	20.1	*26.6*	*20.2*	*18.8*
A48	31.9	25.7	*29.4*	*22.7*	*21.7*
A469	31.8	25.5	*32.2*	*24.7*	*25.1*
A4119	28.4	22.9	*31.6*	*24.5*	*24.0*
A4161	40.9	33.4	*43.7*	*29.6*	*27.6*
A470	40.8	32.5	*38.1*	*27.6*	*23.8*
A48	45.3	37.1	*37.1*	*28.8*	*27.5*
A4160	38.3	32.1	*40.0*	*28.8*	*27.4*
A4232	43.1	34.3	*32.1*	*27.5*	*26.9*
A4055	34.9	28.4	*31.4*	*25.5*	*24.0*
A470	35.6	28.5	*37.3*	*29.1*	*27.1*
A470	31.3	24.6	*41.3*	*30.0*	*23.8*
A48	59.6	45.4	*36.4*	*27.9*	*27.1*
A4232	52.5	40.7	*30.1*	*24.8*	*23.4*
A4119	27.5	21.6	*28.8*	*22.3*	*19.8*
A4161	41.2	31.9	*55.7*	*41.1*	***31.9***
A4055	35.8	29.1	*31.6*	*24.5*	*22.8*
A4234	44.6	36.8	*38.2*	*26.3*	*26.6*
A4232	33.6	26.4	*21.7*	*17.5*	*17.0*
A4232	42.2	29.9	*35.3*	*28.9*	*27.5*
A4160	26.9	21.2	*21.0*	*18.1*	*17.4*
A470	26.5	22.2	*26.9*	*21.8*	*21.6*
A470	35.4	25.3	*34.8*	*25.2*	*20.8*
A4050	30.2	23.1	*32.5*	*25.0*	*24.2*

Note: local results are colour coded as green for less than 35µgm^{-3}, amber between 35µgm^{-3} and 40 µgm^{-3} and red for greater the 40µgm^{-3} (the compliance threshold). Numbers are rounded to the nearest integer, hence any values less than 40.5 µgm^{-3} are not counted as exceedances

Table 8 shows that the preferred option scenario gives lower concentrations that the local baseline 2021 results on all but two road links and compared to the PCM model results are all lower but 8 of the 42 links. For the 8 links where concentrations are higher, they are generally only slightly higher (<3 µgm-3) but the exception is link ID 30660 (A4119) where the locally modelled concentration is much higher than the PCM value. However all local modelled results at this link have always shown higher NO_2 concentrations compared to the PCM model.

The results shows that the preferred CASAP scenario gives lower concentrations for the majority of links compared to other modelled scenarios presented in the Interim Plan (between 76% and 93% of the links show lower concentrations in the preferred scenario than in the CASAP 2-3 and CAZ 1-2 scenarios). The exception is the comparison with CASAP 1, where the preferred scenario shows just over half of the links with higher concentrations than in CASAP 1, likely due to diversionary effects of the city centre traffic scheme.

Figure 6- PCM Links Local Model Results for Preferred Option - 2021



3.3.1 Results at Local Monitoring Locations

Modelled 2021 NO_2 concentration results for the preferred option at each of the monitoring locations used for reporting on Local Air Quality Management purposes have been calculated, and are detailed in Table 9 below. The baseline 2021 data has been provided for reference. Sites that were introduced after 2015 have been removed as site specific adjusted data cannot be calculated based on the 2015 results.

These results provide an indication of whether compliance is predicted at monitoring locations in 2021. In this case the preferred options scenario shows compliance with the 40 µg/m3 limit value for all sites by 2021.

This is an important aspect of the assessment as it further demonstrates that the non charging measures not only deliver compliance but further improve and reduce relevant exposure in terms of LAQM across Cardiff as whole, which will provide further public health benefits.

Table 9 - Predicted NO_2 Annual Mean Concentrations at Monitoring Site Locations in 2015 & 2021 (with Preferred Option)

Monitoring site name	Site ID	NO_2 annual mean ($\mu g.m^{-3}$)	
		Baseline 2021	Preferred Option 2021
Ninian Park Road	16	14.2	13.7
Mitre Place	33	31.5	28.5
City Road	44	20.4	19.6
Mackintosh Place	45	23.4	23.8
Penarth Road	49	17.1	15.9
Birchgrove Village	56	17.1	15.9
Westgate Street	58	30.3	22.4
Stephenson Court	81	25.3	23.5
104 Birchgrove Road	82	18	16.5
497 Cowbridge Road West	85	15.2	14.4
19 Fairoak Road	86	19	18.6
Manor Way Junction	96	23.2	20.9
Newport Road (premises)	97	21.4	20.4
Western Avenue (premises)	98	18.2	17.4
Cardiff Road Llandaff	99	27.8	25.2
Cardiff AURN	101	18.4	16.8
Cardiff AURN	102	18.4	16.8
Cardiff AURN	103	18.4	16.8
30 Caerphilly Road	106	24.6	22.3
Lynx Hotel	107	21.6	20.7
98 Leckwith Road	111	15.3	14.5
17 Sloper Road	112	17.2	16.5
21 Llandaff Road	115	15.2	14.4

Monitoring site name	Site ID	NO_2 annual mean ($\mu g.m^{-3}$)	
		Baseline 2021	Preferred Option 2021
25 Cowbridge Road West	117	20	18.4
Havelock Street	119	22.3	19.3
287 Cowbridge Road East	124	14.4	13.5
Westgate Street Flats	126	27.6	20.9
117 Tudor Street	128	16.1	15.6
Stephenson Court 2	129	23.9	22.5
Burgess Court	130	24.5	23
Dragon Court	131	24.7	23.1
St Mark's Avenue	133	28.1	25.9
Sandringham Hotel	134	18.8	16.8
Lower Cathedral Road	139	19.8	17.7
Clare Street	140	21.2	19.2
Fairoak Road 2	141	18.9	17.8
Windsor House	143	27.9	20.9
Marlborough House	144	26.6	20.3
Tudor Street Flats	145	24.3	22.1
Neville Street	146	19.8	18.2
211 Penarth Road	147	17.5	16
161 Clare Road	148	18	16.8
10 Corporation Road	149	16.5	15.5
James Street	152	22	21.6
Magic Roundabout	153	21.6	21.1
2a/4 Colum Road	156	18.5	17.6
47 Birchgrove Road	157	20.8	19.3
64/66 Cathays Terrace	158	18	16.8
IMO façade replacement	159	22.6	21.7
High Street Zizzi	160	20.6	17.7
52 Bridge Road	161	18.9	17.4
58 Cardiff Road	162	18	16.6
118 Cardiff Road	163	19.4	18.6
725 Newport Road	164	16.6	15.6
6 Heol Tyrrell	165	13.2	12.8
163 Lansdowne Road	166	16.9	16.2
359 Lansdowne Road	167	17	16
570 Cowbridge Road East	168	18.7	17.5
11 Pengam Green	170	17.6	17.8
23 Tweedsmuir Road	171	17.9	18.1
Ocean Way 1	172	18.9	18.5
Ocean Way 2	173	19.6	19.2

Monitoring site name	Site ID	NO_2 annual mean ($\mu g.m^{-3}$) Baseline 2021	NO_2 annual mean ($\mu g.m^{-3}$) Preferred Option 2021
76 North Road	174	23.9	20.1
Castle Arcade	176	**42.7**	33.3
Angel Hotel	177	33.1	24.9
Park Street/Westgate Street	178	32	24.4
Altolusso, Bute Terrace	179	26.3	23.5
Station Terrace	183	32.1	23.6
Hophouse, St Mary Street	184	29.3	23.3
Northgate House, Duke Street	185	27.2	22.3
Dempsey's Public House, Castle Street	186	**40.5**	31.5
Angel Hotel	187	32.8	24.4
Westgate Street (45 Apartments)	188	35.1	28.3
3 Pearson Street	190	16.5	16
7 Mackintosh Place	191	23.7	24
3 Cowbridge Road West	192	18.8	17.4
24 Kings Road	193	20.1	21.9
115 Cowbridge Road West	194	16.6	15.6
244 Newport Road	195	24.8	23.6
2 Pencisely Road	196	18.1	17.4
GFF 369 Newport Road	197	20.1	19.5
Next Building to Stephenson Court	198	20	19.2
157 Newport Road	199	20	19.2
350 Whitchurch Road	200	25.7	24.1
23 Lower Cathedral Road	201	18.4	16.8
22 Clare Street	202	19.6	18.1
10 Fairoak Road	203	16.3	15.4
53 Neville Street	204	16.8	15.7
Fitzalan Court, Newport Road	205	22.1	20.8
Windsor House, Windsor Lane	206	21.9	19.6
42 Waungron Road	207	15.6	14.5
2 Llantrisant Road	208	17.7	15.9
178 North Road	209	22.7	18.3
485 Caerphilly Road	210	19.6	17.2
19 Well Wood Close, Penylan	211	17.2	16.5
62 Bridge Road	212	22.9	19.6

3.3.2 Modelling Uncertainty

The city-wide model used to predict NO_2 concentrations is a large and complex model comprising many thousands of road links, a large amount of input data and a number of modelling assumptions. Both the transport and air quality modelling teams have followed all the appropriate guidance to produce as robust a model as possible. However, it needs to be recognised there is always inherent uncertainly in such models and this needs to be taken in consideration when interpreting the results.

Both the transport and air quality models have been validated. In terms of the air quality model a direct assessment of uncertainty is carried out for the baseline model year (2015) as part of the validation process against monitored air quality data. In this process model performance and uncertainty is assessed using the Root Mean Square Error (RMSE) for the observed vs. predicted NO_2 annual mean concentrations, as detailed in Technical Guidance LAQM.TG (16). In this case the RMSE was calculated at 5.1 µg.m-3. This can then be used as a measure of error on forecast results for future years. This error metric has been used when considering the results by considering locations over 35 $\mu g.m^{-3}$ as being at risk of exceedance. More details on this validation exercise can be found in Appendix A.

However, when assessing future years there will also be uncertainty related to the forecast assumptions we have made in modelling future years. The key assumptions relate to:

- The forecast of traffic activity in the traffic model which is related to local development factors and national growth factors;
- Forecasting the local fleet composition from the ANPR data to future years, this has been done using national trends.

One particular area of forecasting that bears further exploration is the use of the split transport model in 2021 with compliant and non-compliant vehicles. This split is not used for the 2015 traffic modelling. As such we are not strictly comparing like with like going from 2015 to 2021. However, going forward an assessment of additional scenarios taking account of expected policy options will be carried out, and for this we will need to use the split matrix transport model. It will therefore be more robust to compare these option results with the baseline 2021 results using the split model as well. Splitting the transport model in this way can influence both the traffic flows and speeds and the fleet composition on individual links when comparing with an un-split model. To assess the impact of this we plan to do a sensitivity test by running the un-split 2021 transport model results through the air quality model and comparing this with the current 2015 and 2021 results.

Another area of uncertainly is the emissions data used in the modelling. We have used the latest COPERT emission factors available in line with guidance, however, we are aware that these do not always reflect 'real world' vehicle performance accurately. For example, remote sensing work carried out by Ricardo has shown that LGV emissions, particularly for Euro 5 vehicles, can be significantly higher than the standard emission factors. There is also significant variation within a Euro class. This uncertainty also relates to the primary NO_2 fraction (fNO_2) which can have implications for the NOx to NO_2 conversion process used in the modelling as it can be quite sensitive to fNO_2. Again, we have followed the current guidance on this and used a link-specific fNO_2 derived from modelled primary NO_2 and NOx concentrations at each location.

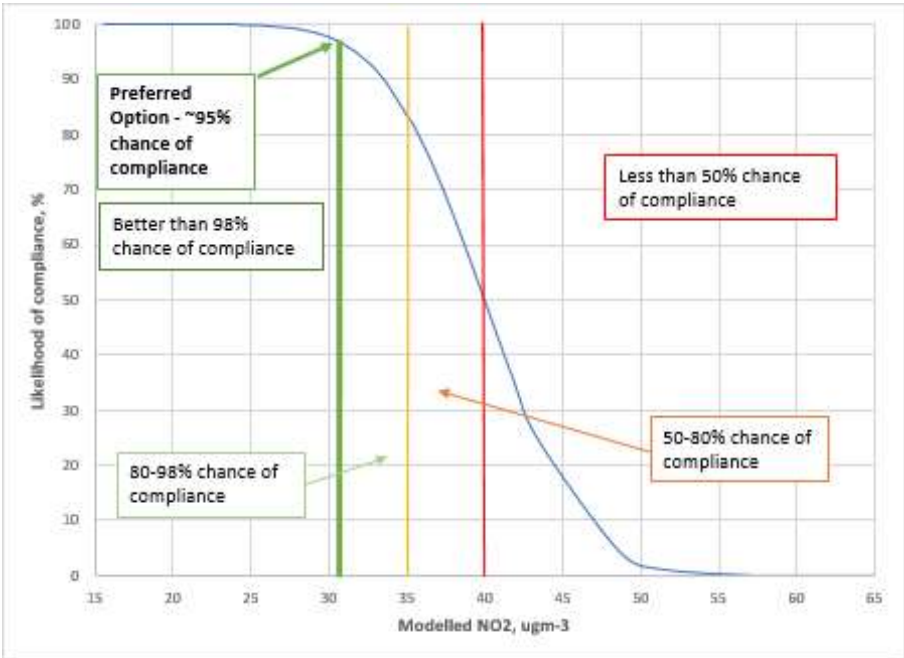
Lastly, the PCM results have been extracted using the 4m buffer as described above, as per guidance. However, in defining relevant receptors along the 4m buffer we also have to account for several other key criteria:

- The receptor location should be representative of 100m length of road;
- It should not be closer than 25m to a major road junction;
- There must be public access – such as a footpath or building.

The sampling is done automatically in a GIS system and the above exceptions removed manually. However, there is some subjectivity around these exceptions such as what constitutes a major junction and how publicly accessible are certain locations. The final results allocated to any given PCM link can be quite sensitive to the final selection of receptors. However, we have taken all endeavours to ensure the final set of receptors used is a reasonable interpretation of the criteria given in the guidance.

With the above detailed it is apparent then that the measures should ensure the greatest level of certainty in terms of achieving compliance. As detailed below in Figure 7, the modelled concentrations of the preferred option at 31.9 µg/m³, give a probability of achieving actual compliance of 95%. This is vitally important in terms of complying with the second legal test of the High Court ruling in the Client Earth 2 case, which requires the Council to demonstrate that compliance is not only obtained in the shortest possible time but that it is likely.

Figure 7 - Probability Distribution Analysis



Model error is an RMSE (root mean square error) of 5 µg/m³ which gives the following probability distribution

3.3.3 Analytical Assurance Statement

A full Analytical Assurance Statement (AAS) has been produced in order to assess the strengths, risks and limitations of the analysis that has been undertaken and the uncertainty in the analytical advice. This assessment allows and decision to be based on the strength of the analysis and how much confidence and weight that it can be relied on in terms of the final decision making process. The full AAS is presented with the Air Quality Modelling Technical report in Appendix A.

3.4 Sensitivity Testing

This section provides the results the sensitivity analyses carried out on the transport and air quality modelling on the preferred option with three key sets of tests undertaken;:

- **Low performance of Euro 6 vehicles** – This test was carried out to assess the impact of Euro 6 light duty vehicles not performing as well as expected in terms of emissions performance. For this test all light duty Euro 6 vehicles were set to the base Euro 6a standard in the model. This test was carried out for the 2021 baseline scenario and preferred option;

- **Lower fNO2 by 40%** - this test was carried out to consider the impact of lower fNO2 as part of the NOx to NO2 conversion process. This was done as new evidence is suggesting the fNO2 may be lower than previously considered for newer vehicles. The test was to reduce fNO2 by 40% for the NOx to NO2 conversion process. This test has been carried out for the 2021 baseline and preferred option; and

- **Preferred Option low test** – this test was used to assess the impact of more pessimistic assumptions in relation to the performance of the measures in the preferred option. The key assumptions where uncertainly was greatest and where a lower assumption was used were:
    - Uptake of the bus retrofit programme – this was reduced from 80% to 50%;
    - Zero uptake of the ULEV taxi grant; and
    - A reduction in the mode shift impact of the active travel measures from 3% to 1%.

The results of the Euro 6 and fNO2 tests are shown in Table 10 and Table 11 and the results of the preferred option low test are shown in Table 12. Further sensitivity tests were undertaken and are presented in full in the Air Quality Modelling Results in Appendix A.

Table 10 - 2021 Baseline Sensitivity Test Results – Maximum Predicted NO2 Annual Mean On PCM Links (Euro 6 Emission Standards Test, And Reduced Fno2 Ratios)

CensusID	Road Name	2021 NO_2 annual mean concentration ($\mu g.m^{-3}$)				
		Baseline	Euro 6 test	% change Euro 6 test	fNO_2 40% reduction test	% change fNO_2 test
30660	A4119	30.7	33.2	8%	28.3	-8%
10629	A4054	19.5	20.9	7%	18.3	-6%
50647	A4119	24.4	26	7%	22.9	-6%
10660	A4161	26.2	28.1	7%	24.6	-6%
522	A48	25.4	28.1	11%	23	-9%
30659	A4119	18.8	20.2	7%	17.8	-5%
77018	A470	30.6	33.1	8%	28.4	-7%
99955	A4160	26.9	28.9	7%	25.4	-6%
50660	A4161	30.8	33.2	8%	28.3	-8%
70055	A4161	30.4	32.8	8%	28.3	-7%
99671	A469	21.5	23.2	8%	20.1	-7%

CensusID	Road Name	2021 NO_2 annual mean concentration ($\mu g.m^{-3}$)				
		Baseline	Euro 6 test	% change Euro 6 test	fNO_2 40% reduction test	% change fNO_2 test
10659	A4160	23.7	25.4	7%	22.4	-5%
10655	A4119	29	31.6	9%	26.3	-9%
80898	A4232	29.5	32.6	11%	26.8	-9%
20527	A48	30.6	33.6	10%	27.7	-9%
40655	A4160	19.3	20.6	7%	18.3	-5%
50580	A469	25.8	28.2	9%	23.7	-8%
50657	A4161	20.3	21.9	8%	19.1	-6%
10661	A4161	20.2	21.8	8%	19.1	-5%
10527	A48	22.7	24.4	7%	21.1	-7%
40582	A469	24.7	26.6	8%	23	-7%
50651	A4119	24.5	26.6	9%	22.6	-8%
40656	A4161	29.6	31.5	6%	27.7	-6%
40549	A470	27.6	29.9	8%	25.3	-8%
50527	A48	28.8	31.4	9%	26.1	-9%
642	A4160	28.8	30.8	7%	27	-6%
80899	A4232	27.5	29.8	8%	25.6	-7%
99960	A4055	25.5	27.8	9%	23.5	-8%
50541	A470	29.1	31.9	10%	26.4	-9%
20548	A470	30	32.1	7%	27.7	-8%
50524	A48	27.9	30.6	10%	25.3	-9%
74101	A4232	24.8	27	9%	22.9	-8%
638	A4119	22.3	23.8	7%	21.1	-5%
30665	A4161	41.1	44.4	8%	36.6	-11%
73233	A4055	24.5	26.6	9%	22.7	-7%
99956	A4234	26.3	28.1	7%	24.9	-5%
78439	A4232	17.5	18.9	8%	16.5	-6%
70056	A4232	28.9	31.8	10%	26.4	-9%
73232	A4160	18.1	19.8	9%	17.1	-6%
80896	A470	21.8	23.2	6%	20.8	-5%
80726	A470	25.2	26.7	6%	23.7	-6%
78435	A4050	25	27.5	10%	22.7	-9%

Table 11 - 2021 Preferred Option – Maximum Predicted NO2 Annual Mean On PCM Links (Euro 6 Emission Standards Test, And Reduced Fno2 Ratios

CensusID	Road Name	2021 NO_2 annual mean concentration ($\mu g.m^{-3}$)				
		Baseline	Euro 6 test	% change Euro 6 test	fNO_2 40% reduction test	% change fNO_2 test
30660	A4119	30.1	32.6	8%	27.7	-8%
10629	A4054	17.7	19.1	8%	16.5	-7%
50647	A4119	22.2	23.8	7%	20.7	-7%
10660	A4161	25.4	27.3	7%	23.8	-6%
522	A48	24.4	27.1	11%	22	-10%
30659	A4119	17.6	19	8%	16.6	-6%
77018	A470	24.1	26.6	10%	21.9	-9%
99955	A4160	26.1	28.1	8%	24.6	-6%
50660	A4161	25.4	27.8	9%	22.9	-10%
70055	A4161	26.6	29	9%	24.5	-8%
99671	A469	20	21.7	9%	18.6	-7%
10659	A4160	21.4	23.1	8%	20.1	-6%
10655	A4119	26.3	28.9	10%	23.6	-10%
80898	A4232	28.6	31.7	11%	25.9	-9%
20527	A48	31.4	34.4	10%	28.5	-9%
40655	A4160	17.7	19	7%	16.7	-6%
50580	A469	24.2	26.6	10%	22.1	-9%
50657	A4161	19	20.6	8%	17.8	-6%
10661	A4161	18.8	20.4	9%	17.7	-6%
10527	A48	21.7	23.4	8%	20.1	-7%
40582	A469	25.1	27	8%	23.4	-7%
50651	A4119	24	26.1	9%	22.1	-8%
40656	A4161	27.6	29.5	7%	25.7	-7%
40549	A470	23.8	26.1	10%	21.5	-10%
50527	A48	27.5	30.1	9%	24.8	-10%
642	A4160	27.4	29.4	7%	25.6	-7%
80899	A4232	26.9	29.2	9%	25	-7%
99960	A4055	24	26.3	10%	22	-8%
50541	A470	27.1	29.9	10%	24.4	-10%
20548	A470	23.8	25.9	9%	21.5	-10%
50524	A48	27.1	29.8	10%	24.5	-10%
74101	A4232	23.4	25.6	9%	21.5	-8%
638	A4119	19.8	21.3	8%	18.6	-6%
30665	A4161	31.9	35.2	10%	27.4	-14%
73233	A4055	22.8	24.9	9%	21	-8%
99956	A4234	26.6	28.4	7%	25.2	-5%
78439	A4232	17	18.4	8%	16	-6%

CensusID	Road Name	2021 NO_2 annual mean concentration ($\mu g.m^{-3}$)				
		Baseline	Euro 6 test	% change Euro 6 test	fNO_2 40% reduction test	% change fNO_2 test
70056	A4232	27.5	30.4	11%	25	-9%
73232	A4160	17.4	19.1	10%	16.4	-6%
80896	A470	21.6	23	6%	20.6	-5%
80726	A470	20.8	22.3	7%	19.3	-7%
78435	A4050	24.2	26.7	10%	21.9	-10%

Table 12 – 2021 Preferred Option – Comparison Of Modelled NO2 Annual Mean Concentrations With Core Assumed Positive Feedbacks And Low Positive Feedbacks

CensusID	Road Name	2021 NO_2 annual mean concentration ($\mu g.m^{-3}$)		
		Preferred Option(Core)	Preferred Option (Low)	% change in concentration
30660	A4119	30.1	29.6	-2%
10629	A4054	17.7	18.1	2%
50647	A4119	22.2	23.2	5%
10660	A4161	25.4	25.5	0%
522	A48	24.4	24.4	0%
30659	A4119	17.6	17.8	1%
77018	A470	24.1	27.2	13%
99955	A4160	26.1	26.3	1%
50660	A4161	25.4	26.6	5%
70055	A4161	26.6	26.9	1%
99671	A469	20	20.2	1%
10659	A4160	21.4	21.6	1%
10655	A4119	26.3	26.6	1%
80898	A4232	28.6	28.4	-1%
20527	A48	31.4	31.3	0%
40655	A4160	17.7	17.9	1%
50580	A469	24.2	24.3	0%
50657	A4161	19	19	0%
10661	A4161	18.8	18.6	-1%
10527	A48	21.7	21.7	0%
40582	A469	25.1	25.2	0%
50651	A4119	24	24.1	0%
40656	A4161	27.6	28.1	2%
40549	A470	23.8	23.9	0%
50527	A48	27.5	27.5	0%
642	A4160	27.4	27.3	0%

CensusID	Road Name	2021 NO_2 annual mean concentration ($\mu g.m^{-3}$)		
		Preferred Option(Core)	Preferred Option (Low)	% change in concentration
80899	A4232	26.9	26.7	-1%
99960	A4055	24	24	0%
50541	A470	27.1	27.2	0%
20548	A470	23.8	24.5	3%
50524	A48	27.1	27.2	0%
74101	A4232	23.4	23.3	0%
638	A4119	19.8	20.4	3%
30665	A4161	31.9	34.6	8%
73233	A4055	22.8	22.8	0%
99956	A4234	26.6	26.3	-1%
78439	A4232	17	17	0%
70056	A4232	27.5	27.5	0%
73232	A4160	17.4	17.3	-1%
80896	A470	21.6	21.5	0%
80726	A470	20.8	22	6%
78435	A4050	24.2	24.2	0%

Based on the results presented in the above tables the following conclusions on the sensitivity test on the preferred option can be summarised as follows:

- **Lower performance of Euro 6** – this test increased concentrations in the 2021 baseline by between 1.3 $\mu g.m^{-3}$ and 3.3 $\mu g.m^{-3}$ with an average 2 $\mu g.m^{-3}$. This increased the exceedance on Castle Street from 41.1 $\mu g.m^{-3}$ to 44.4 $\mu g.m^{-3}$ but did not generate any new exceedances. The impact of this test on the preferred CASAP option was to increase the concentration on Castle Street to a maximum of 35.2 $\mu g.m^{-3}$ still well under the compliance limit value;

- **Lower fNO2 by 40%** - this significantly reduces concentrations by between 1 $\mu g.m^{-3}$ and 5 $\mu g.m^{-3}$. This removes the exceedance on Castle Street and only serves to improve the outcome of the preferred CASAP option.

- **CASAP low test** – this increased concentrations from between 0 and 3 $\mu g.m^{-3}$, with the result on Castle Street increasing from 31.9 $\mu g.m^{-3}$ to 34.6 $\mu g.m^{-3}$. If this test is combined with the worst-case impact of the Euro 6 test the result on Castle Street would increase to a maximum of 37.9 $\mu g.m^{-3}$ so is still achieving the limit value.

This indicates that the preferred CASAP package is robust under the sensitivity tests carried out, in terms of its ability to achieve compliance

3.5 Charging Clean Air Zone Comparison

As previously detailed in the Interim Plan, the Council assessed two CAZs as a benchmarking exercise to assess whether they could achieve compliance sooner than the non charging measures.

In order to provide a robust appraisal of preferred option, the CAZ 1 option has been taken forward into the economic appraisal and distributional impact analysis for comparative purposes as this option was also demonstrated to achieve compliance as reported in the Interim Plan. Full details of how the CAZ 1 scenario was modelled is detailed in the Interim Plan. The previous section clearly shows that preferred option achieves compliance by 2021.

The Council has concerns that the likelihood of implementing a CAZ before 2021, is not entirely feasible. In terms of this timeframes for implementation of any CAZ this would need to include all provisions for designing, detailed public consultation, confirmation of the order from Welsh Government under Section S.169 (1) of the Transport Act 2000[31], and implementing a CAZ (including procurement of all necessary hardware and software and the development of appropriate operational capabilities, including recruitment of necessary back office staff).

In addition there is currently no finalised CAZ framework available in Wales and no finalised guidance in terms of setting charging, or exemptions (which may require the passing of new legislation by Welsh Government under Section 172 of the Transport Act.

3.5.1 Clean Air Zone 1

Having considered the results of the baseline do nothing scenario, and following a work shop to assess likely CAZ scenarios it was agreed that the most effective CAZ to model would be a Small City Centre zone, with only private cars that did not meet the emission standards laid out in the draft CAZ framework would be affected. It was agreed that a nominal £10 daily charge would be applied to all non-compliant private vehicles. Figure 8 below details the extent of the CAZ that was modelled.

[31] **Transport Act 2000 (amended by LTA 2008)**

Figure 8 - CAZ Boundary for Benchmark Exercise

It should be noted that during the workshop both group and round table discussions took place to assess what would be the preferred CAZ scenario to deliver compliance, and be modelled in full in the feasibility study. Three groups discussed one CAZ scenario each, these being:

1. Citywide CAZ
2. Medium sized CAZ bordering A48 & A4232
3. City Centre CCAZ

The members of the workshop were then asked to rank what they felt was the most appropriate CAZ to be taken forward for the benchmarking exercise in terms of identifying an option to deliver compliance in the shortest possible time.

Table 13 below summarises the outputs of the workshop and the preferred scenario.

Table 13 - CAZ Workshop Output Summary

CAZ Option	Positives	Negatives	Outcome
Citywide CAZ- Target all vehicles	-Address LAQM and National objectives; -Equality in charging all road users; -Complies with WFG Act 2015; -Revenue generation maximised enabling	-Extremely difficult to model and time constraints of study; -Large scale infrastructure required; -Potential implications for neighbouring	Least favoured option from workshops

CAZ Option	Positives	Negatives	Outcome
	future investment in mitigation measures	authorities and wider displacement impacts; -not proportionate to the scale of non compliance of base ; - will not have acceptance;	
Medium CAZ- Target all vehicles (Private, Commercial & HGVs). Daily and Internal movement charge. Potential to include City Centre Zone as a 'donut' effect	-More inline with WFG Act 2015; -Will lead to a widespread positive impact to air quality encapsulating AQMAs; -Address LAQM and National Standards.	-Potentially lead to social inequality; -Large scale infrastructure required; -Modelling is complex for both transport and air quality; -not proportionate to the scale of non compliance in baseline model; - will not have wide acceptance	Medium CAZ only - no donut effect second most popular.
City Centre CAZ- Target Private Vehicles (Diesel & Petrol). Daily Charge	Targets the issue of non-compliance directly ; -Feasible to model in the given time constraints; -Small area with sufficient car parking available outside the perimeter; -more likely to be implemented in shorter time use of existing infrastructure; -Manageable; -Proposed not to create an imbalance to social equality; -Provide residents within the boundary with a grace period to upgrade vehicles; -possibly only applicable to weekdays only no impact on weekend economy	-Vehicles will be able to move around and within the boundary; -Expected impact to businesses within the boundary; -Considered not in line with WFG 2015; -Potential conflict with public understanding why the commercial/ public transport exemption.	Most popular option from workshop and taken forward for detailed transportation and air quality modelling.

As detailed above, owing to the results of our baseline local modelling whereby we identified compliance issues in the City Centre specifically on Castle Street, the consensus of the workshop agreed that a small city centre CAZ would be a proportionate area to assess. Owing to the time limitation of the direction the professional advice from our consultants was that it would not be possible to fully model further additional larger CAZs at this stage.

3.5.2 Comparison with PCM Results

In line with the modelled baseline and the preferred option, the results for the CAZ scenarios have been generated for each of the PCM road links. A full list of tabulated results for the PCM road links for the modelled year of 2021 is shown in Table 14, along with the baseline results and results from the preferred option for comparison. Mapped results of the CAZ 1 scenario is in Figure 9.

The results for CAZ 1 that NO_2 concentrations are estimated to be lower than the baseline 2021 scenario at most links, although increases are shown on 6 links. The largest decrease observed in both CAZ 1 is at link ID 30665 (A4161, Castle Street), as might be expected for a measure that is specifically targeting the city centre.

Compared to the preferred option, **most links show higher concentrations in the CAZ scenarios**.

Table 14 - PCM and Local Model NO_2 Concentration Results for Preferred Option and CAZ1

Census ID	Road Name	PCM Baseline		Local Baseline		Preferred Option	CAZ1
		2015	2021	2015	2021	2021	2021
30660	A4119	22.4	17.9	*37.1*	*30.7*	*30.1*	*30.7*
10629	A4054	19.1	15.0	*25.3*	*19.5*	*17.7*	*19.3*
50647	A4119	29.9	24.0	*34.4*	*24.4*	*22.2*	*23.5*
10660	A4161	40.3	32.7	*34.9*	*26.2*	*25.4*	*25.6*
522	A48	27.9	22.3	*32.9*	*25.4*	*24.4*	*25.1*
30659	A4119	27.2	21.8	*23.8*	*18.8*	*17.6*	*18.4*
77018	A470	31.1	25.2	*45.4*	*30.6*	*24.1*	*28.2*
99955	A4160	32.2	25.7	*36.7*	*26.9*	*26.1*	*25.4*
50660	A4161	43.7	33.8	*42.2*	*30.8*	*25.4*	*25.8*
70055	A4161	37.5	29.7	*43.9*	*30.4*	*26.6*	*27.8*
99671	A469	33.1	27.1	*27.2*	*21.5*	*20.0*	*21.1*
10659	A4160	30.4	25.0	*30.4*	*23.7*	*21.4*	*22.6*
10655	A4119	31.9	25.9	*36.6*	*29.0*	*26.3*	*27.9*
80898	A4232	47.3	37.7	*34.3*	*29.5*	*28.6*	*29.5*
20527	A48	48.8	39.1	*40.0*	*30.6*	*31.4*	*31.5*
40655	A4160	28.2	22.7	*24.2*	*19.3*	*17.7*	*18.8*
50580	A469	28.5	22.4	*33.0*	*25.8*	*24.2*	*25.5*
50657	A4161	29.5	23.3	*26.5*	*20.3*	*19.0*	*19.6*
10661	A4161	24.9	20.1	*26.6*	*20.2*	*18.8*	*19.6*
10527	A48	31.9	25.7	*29.4*	*22.7*	*21.7*	*22.2*
40582	A469	31.8	25.5	*32.2*	*24.7*	*25.1*	*24.5*
50651	A4119	28.4	22.9	*31.6*	*24.5*	*24.0*	*25.1*
40656	A4161	40.9	33.4	*43.7*	*29.6*	*27.6*	*27.8*
40549	A470	40.8	32.5	*38.1*	*27.6*	*23.8*	*25.5*
50527	A48	45.3	37.1	*37.1*	*28.8*	*27.5*	*28.4*
642	A4160	38.3	32.1	*40.0*	*28.8*	*27.4*	*28.2*
80899	A4232	43.1	34.3	*32.1*	*27.5*	*26.9*	*27.4*

Census ID	Road Name	PCM Baseline		Local Baseline		Preferred Option	CAZ1
		2015	2021	2015	2021	2021	2021
99960	A4055	34.9	28.4	31.4	25.5	24.0	24.8
50541	A470	35.6	28.5	37.3	29.1	27.1	28.2
20548	A470	31.3	24.6	41.3	30.0	23.8	25.9
50524	A48	59.6	45.4	36.4	27.9	27.1	27.7
74101	A4232	52.5	40.7	30.1	24.8	23.4	24.1
638	A4119	27.5	21.6	28.8	22.3	19.8	21.3
30665	A4161	41.2	31.9	55.7	41.1	**31.9**	32.5
73233	A4055	35.8	29.1	31.6	24.5	22.8	23.8
99956	A4234	44.6	36.8	38.2	26.3	26.6	26.1
78439	A4232	33.6	26.4	21.7	17.5	17.0	17.5
70056	A4232	42.2	29.9	35.3	28.9	27.5	30.1
73232	A4160	26.9	21.2	21.0	18.1	17.4	17.9
80896	A470	26.5	22.2	26.9	21.8	21.6	22.0
80726	A470	35.4	25.3	34.8	25.2	20.8	21.6
78435	A4050	30.2	23.1	32.5	25.0	24.2	25.0

Note: local results are colour coded as green for less than 35µgm-3, amber between 35µgm-3 and 40 µgm-3 and red for greater the 40µgm-3 (the compliance threshold). Numbers are rounded to the nearest integer, hence any values less than 40.5 µgm-3 are not counted as exceedances.

3.5.3 CAZ 1 Results at Local Monitoring Locations

Modelled NO_2 concentrations for CAZ 1 have been calculated for each of the monitoring locations, and are shown in Table 15 below.

These results provide an indication of whether compliance is predicted at monitoring locations in 2021. In this case CAZ 1 also shows compliance with the 40 µg/m^3 limit value for all sites by 2021.

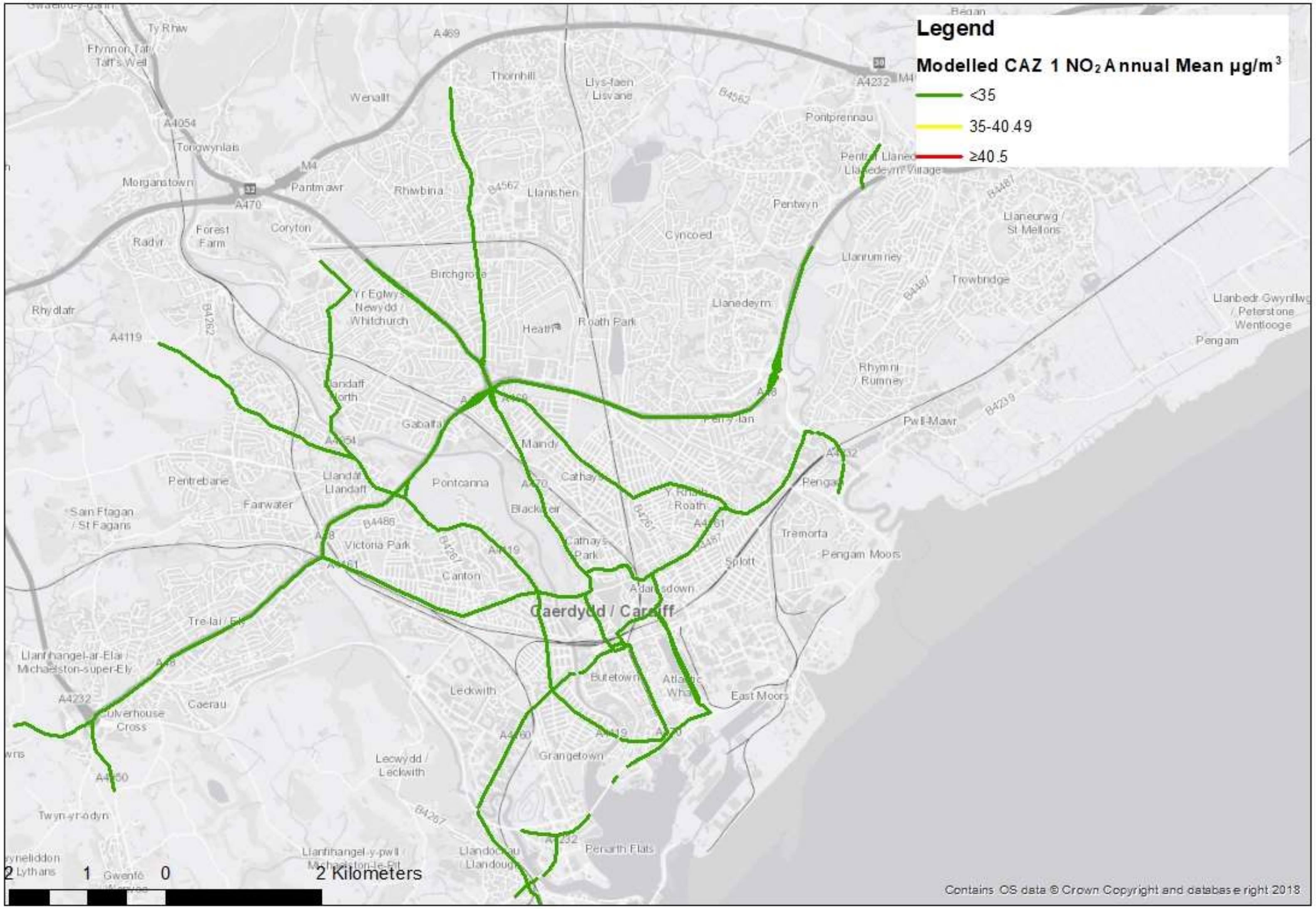
Table 15 - Predicted NO_2 Annual Mean Concentrations at Monitoring Site Locations in 2021 with CAZ 1

Monitoring site name	Site ID	NO_2 annual mean (µg.m^{-3})	
		Baseline 2021	CAZ 1 2021
Ninian Park Road	16	14.2	13.9
Mitre Place	33	31.5	30.3
City Road	44	20.4	19.7
Mackintosh Place	45	23.4	23.1
Penarth Road	49	17.1	16.5
Birchgrove Village	56	17.1	16.7
Westgate Street	58	30.3	24.5
Stephenson Court	81	25.3	24.1
104 Birchgrove Road	82	18	17.5
497 Cowbridge Road West	85	15.2	15

Monitoring site name	Site ID	NO_2 annual mean ($\mu g.m^{-3}$)	
		Baseline 2021	CAZ 1 2021
19 Fairoak Road	86	19	18.8
Manor Way Junction	96	23.2	22.2
Newport Road (premises)	97	21.4	20.8
Western Avenue (premises)	98	18.2	17.8
Cardiff Road Llandaff	99	27.8	26.7
Cardiff AURN	101	18.4	17.2
Cardiff AURN	102	18.4	17.2
Cardiff AURN	103	18.4	17.2
30 Caerphilly Road	106	24.6	23.6
Lynx Hotel	107	21.6	21.1
98 Leckwith Road	111	15.3	15.1
17 Sloper Road	112	17.2	17
21 Llandaff Road	115	15.2	15
25 Cowbridge Road West	117	20	19.2
Havelock Street	119	22.3	20.6
287 Cowbridge Road East	124	14.4	14.2
Westgate Street Flats	126	27.6	22.7
117 Tudor Street	128	16.1	15.7
Stephenson Court 2	129	23.9	22.8
Burgess Court	130	24.5	23.3
Dragon Court	131	24.7	23.5
St Mark's Avenue	133	28.1	27.7
Sandringham Hotel	134	18.8	17.7
Lower Cathedral Road	139	19.8	18.8
Clare Street	140	21.2	20.5
Fairoak Road 2	141	18.9	18.5
Windsor House	143	27.9	23
Marlborough House	144	26.6	22.4
Tudor Street Flats	145	24.3	23.9
Neville Street	146	19.8	19
211 Penarth Road	147	17.5	16.9
161 Clare Road	148	18	17.3
10 Corporation Road	149	16.5	16.1
James Street	152	22	22
Magic Roundabout	153	21.6	21.5
2a/4 Colum Road	156	18.5	18.2
47 Birchgrove Road	157	20.8	20.2
64/66 Cathays Terrace	158	18	17.4
IMO façade replacement	159	22.6	22
High Street Zizzi	160	20.6	18.4

Monitoring site name	Site ID	NO_2 annual mean ($\mu g.m^{-3}$)	
		Baseline 2021	CAZ 1 2021
52 Bridge Road	161	18.9	18.4
58 Cardiff Road	162	18	17.5
118 Cardiff Road	163	19.4	19.3
725 Newport Road	164	16.6	16.3
6 Heol Tyrrell	165	13.2	13
163 Lansdowne Road	166	16.9	16.4
359 Lansdowne Road	167	17	16.4
570 Cowbridge Road East	168	18.7	18.1
11 Pengam Green	170	17.6	17.5
23 Tweedsmuir Road	171	17.9	17.8
Ocean Way 1	172	18.9	18.9
Ocean Way 2	173	19.6	19.6
76 North Road	174	23.9	22.1
Castle Arcade	176	**42.7**	32.9
Angel Hotel	177	33.1	26.4
Park Street/Westgate Street	178	32	29

Figure 9 - PCM Links Colour Coded With CAZ 1 Results In 2021



3.6 Economic Appraisal

The Joint Air Quality Unit (JAQU) have provided detailed guidance regarding the economic appraisal of mitigation options. This provides a steer for many of the key data inputs and assumptions that have framed how the analysis is undertaken. The key guidance documents include:

- Options Appraisal – Guidance (2018)[32] (and preceding versions of this guidance)
- National data inputs for Local Economic Models (2018)[33].

The below analysis is based on this guidance as well as using TUBA (Transport Users Benefit Analysis), the Propensity to Cycle Tool[34] (PCT) and the Active Travel Toolkit as per Department for Transport (DfT) WebTAG Unit A5-1[35] to perform analysis of the transport impacts in accordance with transport appraisal guidance.

The analysis is underpinned by the following general assumptions:

- Each impact is assessed relative to a 'do minimum' counterfactual
- All impacts are presented in real terms with a Price Year of 2018.
- All impacts are discounted to 2018 applying Green Book discount factor of 3.5%.

The Full Economic Analysis report is presented in Appendix F of this report, and is referenced as Economic Appraisal Methodology Report produced by Ricardo. This following section provides a summary of this assessment.

3.6.1 Scope of Impacts Assessed

Any scheme to tackle air quality will impact different parts of the environment, economy and society. The economic analysis seeks to quantify and value as many of these impacts as possible given the time, resource and modelling methodologies available.

JAQU's guidance sets the basis for the scope of impacts to be assessed for a Charging Scheme appraisal. We have adopted the same approach to the CASAP measures although some of the impacts may not be relevant. In some cases, we have grouped impacts by the methodology taken to appraise them and hence may in places refer to different impacts using different terminology to that set out in the JAQU guidance.

The scope of impacts captured by the CBA, and their correspondence to the impact categories described in the JAQU guidance, are presented in Table 16.

Table 16 - Impact Description and Mapping

Impact name	Description	JAQU reference
Upgrade costs	The impact on those vehicles owners that respond to Charging Scheme. These are the upfront costs for vehicle owners associated with switching from a non-compliant to a compliant vehicle. This encompasses the vehicle scrappage cost and the consumer welfare impact as described in the JAQU guidance. These will not be considered as part of the CASAP Packages Scheme.	'Vehicle scrappage costs' and 'Consumer welfare impact' for 'upgrade vehicle response'

[32] Unpublished – provided directly by JAQU to cities
[33] Unpublished – provided directly by JAQU to cities
[34] https://www.pct.bike/
[35] Active Mode Appraisal (May 2018)

Impact name	Description	JAQU reference
Operating cost impacts	Those savings or additional costs that can result from Charging Scheme or CASAP Packages Measure. This includes both changes in fuel consumption and the associated cost and change in operating and maintenance costs. This can come about through additional distances travelled (handled by TUBA) or change in vehicle type (handled by REE model).	'Fuel switch costs'
Implementation costs (Investment and Operating Costs)	Cost of upfront and ongoing activity and assets required to implement, monitor and enforce the Charging Scheme, and CASAP Packages measure by the administering authority.	'Government costs'
Air quality emissions	The impact on affected populations by a change in NOx and PM emissions as a result of Charging Scheme and CASAP Package implementation	'Health and environmental impact'
Greenhouse Gas impacts	The impact on affected populations by a change in greenhouse gas emissions that result from Charging Scheme and CASAP Packages measure implementation. This can come about through additional distances travelled or change in vehicle type.	'Greenhouse Gas impacts'
Travel Time	The impact of the Charging Schemes and CASAP Package measure on traffic flow and the subsequent impact on travel time experienced by affected populations.	'Traffic flow impact'
User Charges	The cost to road users from paying the CAZ charges. This category includes for impact on consumer welfare associated with the user not being able to take their first preference. E.g. in the case of 'cancelled' journeys, the vehicle user will not be able to undertake the activity planned at the destination (e.g. shopping trip to city centre). The vehicle user will miss out on the happiness / value that they would have gained from that trip, which is captured by this impact category.	'Consumer welfare impact'
User Charge Revenues	The revenue generated through charging the non-compliant cars to travel through the CAZ. This should have no net impact on the model.	'Government costs'
Indirect Tax Revenues	The impact on revenues generated by the VAT, excises and duties levied on goods and services. This should have no net impact on the model.	'Government costs'
Walking and Cycling	The incentive to use non-motorised transport modes when an Active Travel package is implemented (cycling and walking) has a benefit on the affected population in the following ways: congestion benefit, change in the number of accidents, better local air quality, changes in noise levels, reduction of Greenhouse gases, potential reduced risk of premature death, absenteeism, journey Ambience and indirect taxation. To avoid double counting, our model includes only the following impacts: Accidents, Noise, Reduced risk of premature death, Absenteeism, Journey Ambience.	'Health and environmental impact'

Modelling has been split between TUBA, the Active Travel Toolkit and Ricardo's economic models as shown in Table 17.

Table 17 - Allocation of Impact Categories

Impacts	CASAP 3	Charging Schemes CAZ 1
Upgrade costs	✓ - REE Economic Model	✓ - REE Economic Model
Implementation	✓ - REE Economic Model (based on CCC data)	✓ - REE Economic Model (based on CCC data)
Welfare loss (rule of half) (Cost changes for altered trips)	✓ - TUBA	✓ - TUBA
Air quality	✓ - REE Economic Model	✓ - REE Economic Model
Time (Cost changes for unaltered trips)	✓ - TUBA	✓- TUBA
OPEX/Fuel/CO2 (distance)	✓ - TUBA	✓ -TUBA
OPEX/Fuel/CO2 (upgrades)	✓ - REE Economic Model	✓ - REE Economic Model
User Charge Revenues/ Indirect Tax Revenues	✓ -TUBA	✓ -TUBA
Walking and Cycling	✓ - Active Travel Toolkit	-

TUBA presents a value for indirect taxation. This is because of the market price unit of account that is used in TUBA. It reflects the relevant indirect taxes paid by different user groups and accrues to public finances. The Ricardo CAZ model adopts the social approach to the CBA which means all costs exclude VAT and therefore no indirect taxation line. However, this is netted off within the TUBA output.

3.6.2 Assessing the Impacts

3.6.2.1 TUBA

TUBA outputs were only available for a single year due to modelling difficulties. This is because TUBA is set up to take inputs from two separate modelled years. This is so that benefits can be interpolated/extrapolated across the entire appraisal period. The work has been carried out using a single modelled year of 2021. TUBA will not accept single year inputs to produce benefits for a multi-year appraisal period but will accept single year inputs to produce an appraisal for a single year. To account for the entire appraisal period of 2021-2030 (inclusive), factors have been calculated to apply to single-year benefits, based upon WebTAG Unit A1.1: Cost Benefit Analysis (the methods described in this unit are the same as those employed within the software). These factors incorporate the effects of:

- Time-related discounting;
- Changing values of time (for VoT-related benefits only); and
- Demand growth.

As a check of this process, TUBA has been run with the 2021 inputs used to represent two different modelled years as a proxy, and output benefit values compared with those produced using the factors described above. The difference between these methodologies is that the latter does not incorporate demand growth.

Demand growth has been incorporated into the factors used to convert single-year benefits. Per-annum demand growth across the appraisal period was calculated using the DfT's 2018 Road Traffic Forecasts (RTF) as shown below in Table 18. The data used was specific to Wales but averaged across all road types.

Table 18 - Background Traffic Growth Rates[36]

	Growth Across Period	Annual Growth
2020-2025	4.62%	0.91%
2025-2030	4.20%	0.83%

3.6.2.2 Vehicle Upgrade costs

A vehicle owner upgrading to cleaner vehicles and the resultant impact on air quality is the key output of each the Charging scheme and vehicle upgrade measures in CASAP. The costs associated with this decision is a critical impact category. Our approach to estimating upgrade costs has been tested in a number of cities considering charging schemes and has been applied in Cardiff when considering the Charging Scheme and Fleet upgrades.

The approach starts by calculating the number of vehicles to be upgraded. For the CASAP measures that has been calculated directly from the fleet data for buses and taxis as described above. For the CAZ this is defined by applying behavioural responses to the non-compliant vehicles in the baseline. It is assumed that the oldest vehicles are the first to upgrade.

The cost to an owner of a change vehicle is then estimated through consideration of the following:

- The lost residual value from scrapped vehicles or the resale value of an unwanted vehicle based on the depreciated value of vehicle in 2021
- New or used vehicle purchase costs in 2021

These input values are combined to give the net cost. Resale costs (if applicable) are netted off the purchase costs and lost residual value associated with each upgrade.

Upgrades will also occur in the baseline and our approach to estimating these costs is very similar to what has been applied when considering the policy option. The general assumption in the baseline is that the same upgrade decision will be undertaken as in the measure but at a later date (defined by useful lives and ownership profiles). This future net cost is discounted (according to how far in the future it occurs) to 2021 to allow comparison with option costs. The exception to this is for the ZEB measure and electric/PHEV taxis which assume that, in the baseline, these vehicles upgrade to standard, Euro 6, diesel/petrol vehicles.

The upgrade costs are calculated taking the difference in aggregate upgrade costs for the option and baseline scenarios. Specific modelling assumptions and data inputs are provided in the Appendix of this document.

3.6.2.3 Air Quality Emissions

The key objective of these policy options is to reduce the emission (and subsequently concentrations) of air pollutant emissions from road transport sources. Reducing air pollutant emissions will have a range of subsequent benefits on human and environmental health, productivity and amenity.
The following approach to valuing the impacts associated with reductions in emissions is as follows:

1. Take quantities (tonnes) of emissions from underlying air quality modelling undertaken by Ricardo for all option scenarios and do minimum baseline
2. Calculate total emissions impact relative to baseline
3. Value impact applying damage costs provided by JAQU

[36] Source:Mott MacDonald from RTF 2018

a. The damage cost 'Urban big' is applied to all emissions reductions under the FBC CASAP and CAZ 1 scenario.

The results of the analysis for 2021 are presented in

Table 19. It should be noted that these are only impacts for a single year, and there is no application of extrapolation factors.

Table 19 - Air Pollutant (Nox And PM2.5) Impacts Of The Measures In 2021

Option	NOx			PM2.5		
	NOx Emissions (t/ year All vehicles)	Difference from Baseline (t)	Benefits per annum (£)	PM2.5 Emissions (t/ year All vehicles)	Difference from Baseline (t)	Benefits per annum (£)
Preferred Option	1819.68	-99.13	£711,915	62.69	-0.34	£43,915
CAZ 1	1,925.63	6.81	-£49,919	65.48	0.99	-£322,085

Results show a decrease in NO_x and $PM_{2.5}$ emissions for FBC CASAP with benefits per annum of £711,915 and £43,915 savings respectively. The results show an increase in NO_x and $PM_{2.5}$ emissions for CAZ 1 with disbenefits per annum of £49,919 and £322,085 costs respectively.

3.6.2.4 Operating costs and Greenhouse Gas Emissions for Upgraded vehicles

Operating costs and greenhouse gas emissions are calculated as part of the TUBA model. This modelling focuses on the additional impacts associated with any change in distance and therefore fuel consumption associated with a particular option. But TUBA does not take into account any change in fuel consumption (and OPEX and GHG impacts) associated with the upgraded fleet that has resulted from the option. Ricardo's model, which has focused on charging schemes that result in a significant change in fleet mix, calculates the changes in fuel costs, OPEX and greenhouse gas emissions. The values used to calculate these operating costs are consistent across the different forms of analysis.

The estimation of operating costs and greenhouse gas emissions focused on capturing the effect of upgrading vehicles, which switches vkm travelled from one Euro class of vehicles to another. The following approach was taken:

1. Take numbers of vehicles upgraded from fleet upgrade calculations
2. Combine numbers of vehicles upgraded by different vehicle type and Euro standards with data around the average annual fuel consumption and average annual operating costs per vehicle type and age[37]
   a. By applying average OPEX and fuel consumption over the full year and average vkm travelled per annum, this illustrative modelling will likely capture an even wider domain of impacts – i.e. will include the impacts where upgraded vehicles travel outside the AQ modelling domain
3. Changes in fuel consumption are combined with changes in fuel prices.

[37] Consumption and OPEX for general vehicle types came from: Ricardo study for TfL (2014): 'Environmental Support to the Development of a London Low Emission Vehicle Roadmap' (unpublished). Data for hybrid vehicles came from: Ricardo Energy & Environment (forthcoming). Car Choice Model (CCM) summary report.

4. Changes in fuel consumption are combined with emissions factors from BEIS' Green Book Supplementary Guidance to calculate changes in GHG emissions (tCO_2e) [38]
5. Changes in GHG emissions in each year are combined with carbon values from BEIS' Green Book Supplementary Guidance.

Note: these impacts are not forecast over the period using the extrapolation factor. This is because these impacts are associated with modelled vehicle upgrades. The model depicts the OPEX and GHG emissions associated with the new vehicle, and with the vehicle replaced to identify the difference. Hence the impacts are already depicted over the appraisal period and the extrapolation factor is not required

3.6.2.5 Implementation costs

Implementation costs are described by JAQU guidance as the costs of implementing a measure in terms of administrative costs. The following assumptions have been applied to calculate the final implementation costs included in the model:

- When looking at the **ZEB costs**, a total of £455,000 covering 45 charge points at £ 10,080 per point, BYD Charging Management System and set-up costs (one-time, including commissioning of the system and training) (see **Error! Reference source not found.**, second and third column). Note this amount does not include any supply/ connection costs.
- In terms of the **retrofit for the buses,** at the time when the model was set up CCC was looking at offering up to 150 buses with costs of £15,000 per bus, giving a total of £2,250,000 (2018) to retrofit 150 buses. These costs are assumed in the REE model for the retrofit bus package to calculate the total upgrading costs. They are not included as such in the implementation costs to avoid double counting.
- The CCC was targeting 620 vehicles which following the change in policy will be required to change to Euro 6 when we developed the model for **taxi licensing**. CCC aimed at contributing £1000 annually over 3 years for the running costs (not purchase) of the vehicles which would equate to a total cost of £3000 per vehicle and a total cost of £1,860,000 for the CCC. Ricardo EE economic model includes not only the purchase but also the running costs (OPEX) to compare the overall benefits of the renovated fleet during the whole appraisal period. Thus, the £1,860,000 costs estimated by the CCC to contributing to the overall costs of taxi licensers are already considered in the REE model and not included as separate implementation costs to avoid double counting.
- In terms of the completion of **Cycle way 1**, the cost estimate is £5,800,000 included in the FBC CBA (see **Error! Reference source not found.**, second and third column). However, it should be noted that the 2019/2020 costs are likely to be funded through the active travel fund (£107,000), so potentially these could be removed as work as already stated on this element if we were to look at non-secured funding costs only (see **Error! Reference source not found.**, fourth and fifth column and Appendix 1 for additional information).
- CCC has a cost estimate of £1,996,480 for the 20mph zones (**Active Travel Package**). This number is thus included as implementation cost in the FBC CBA (see **Error! Reference source not found.**, second and third column). However, it should be noted that bids have already been made for these elements and award announcement is imminent at the time when this study took place, and work has already commenced so potentially these could be removed if we were to look at non-secured funding costs.

38 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/602657/5._Data_tables_1-19_supporting_the_toolkit_and_the_guidance_2016.xlsx

- The **City Centre Programmes** have a total implementation cost of £22,252,000 which is included in the FBC CBA. However, £950,000 have been already spent before 2019, £2,750,000 has been awarded for the 2019/2020 financial year from the Local Travel fund and £500,000 from the City Deal. S106 contributions to the schemes also equates £1,000,000 from the 2019/2020 costs and £250,000 from the 2020/2021. This sums a total of £ £5,450,000[39] that could potentially be removed if we were to look at non-secured funding costs
- **Implementation costs for the CAZ** include the cost to the local authority to set up and run the charging zone, including equipment, and the ongoing costs of ensuring compliance. The numbers are determined by the accessibility of the CAZ area and the number of roads going in and out. There is also an assumed ongoing cost that accounts for maintenance and additional public staff to issue fines, data collection and processing of payments etc. Hence implementation costs are a combination of upfront infrastructure costs and ongoing costs assumed across 10 years.

The additional cycle ways which are included in the AECOM assessment are those that are included in the City Centre Schemes, and thus the costs for those are incorporated into the costs of those schemes and are therefore accounted for.

For the core societal CBA, costs that have already taken place when this analysis was done should be taken into account as they have occurred after 2015, which is the base year for building up the AQ and traffic models and therefore their impacts are taken into account in the FBC CASAP scenario. Only when looking at the costs that still need funding, these will be taken out as they have already occurred. This will be the case for the costs of the Cycle Way 1 and the City Centre Scheme in 2018 (£107,000 and £950,000 respectively) (see Table 20, fourth column). We have presented both for comparison.

In addition, a 36% uplift on any implementation costs has been applied as optimism bias following JAQU guidance.

Table 20 – FBC – Preferred Option Implementation Costs (£2018) Included In the Economic Appraisal

Our assumption	Total costs included		Excluded costs with secured funding	
CCC	-	Opt. Bias (36%)	-	Opt. Bias (36%)
ZEB	-£439,614	-£597,874	-£439,614	-£597,874
Bus retrofit	REE model	REE model	REE model	REE model
Taxi Licensing	REE model	REE model	REE model	REE model
Active Travel Package	-£1,418,357	-£1,928,966	-£1,418,357	-£1,928,966
Cycle Way 1	-£5,532,788	-£7,524,592	-£5,425,788	-£7,379,072
City Centre Programme	-£20,652,037	-£28,086,771	-£15,362,543	-£20,893,058
Net Present Value	**-£28,042,796**	**-£38,138,203**	**-£22,646,302**	**-£30,798,971**

3.6.2.6 Active Travel Toolkit

The demand forecasts using the PCT method have been inputted into the Active Mode Appraisal Toolkit (ATT) as per Department for Transport (DfT) WebTAG Unit A5-1[40] to appraise additional economic benefits related to the following specific FBC CASAP measures: Active Travel package and Cycle Way 1. The impacts appraised all relate to an estimate of the reduction in vehicle km for road users which would occur derived from the modal shift to walk/cycle from car. These include the

[39] Pre-2019/2020: £950,000; 2019: £4,250,000; 2020: £250,000.

[40] Active Mode Appraisal (May 2018). Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/760092/active-mode-appraisal-toolkit.xlsx

following the following impacts: implementation costs, decongestion benefits, accidents, local air quality, noise, greenhouse gases, reduced risk of premature death, absenteeism, journey ambience, indirect tax revenue. The ATT is not considering the wider discouragement to drive into the city centre that the overall package would result in, only the impact of the attractiveness of high-quality cycle infrastructure. However, the quantification of the impacts associated with the rerouting of vehicular traffic which may result in additional vehicle kilometres with associated economic dis-benefits is well captured by TUBA.

The model is based upon a desk-based analysis of the proposed walking and cycle measures on each route. A background growth rate in trips of 0.75% (National Travel Survey Data 2006-2016) has been assumed, with 90% of trips being made considered as return trips and therefore counted twice in the daily journey count. As the three schemes have been appraised separately in the Active Travel Toolkit, the method adopted provides the potential for a limited amount of benefit double counting. Scheme implementation costs have been included separately in the overall analysis.

The assessment period is usually based upon the life expectancy of the infrastructure in question. WebTAG allows to appraise up to a 60 years threshold, but for cycle infrastructure which may have a shorter life expectancy than say a road it is more reasonable to assume 20 years. However, to align with the wider to align with the wider assessment undertaken as part of the air quality study the assessments have been undertaken over a 10-year appraisal period[41] with all scheme assumed to open in 2021. Note that reducing the assessment threshold from 20 to 10 years approximately corresponds to a halving of benefits (see Appendix 2 – Additional Results).

Local air quality, greenhouse gases, and indirect tax revenue have been calculated for the Preferred Option using TUBA and therefore not included in the overall economic appraisal to avoid double counting

3.6.3 Summary of Results

The results of our economic analysis are summarised in Table 21 and Figure 10.

Table 21 - Monetised Impacts Associated With Option Scenarios (Cumulative Discounted Impact (PV) From 2021-31 (£M 2018 Prices))

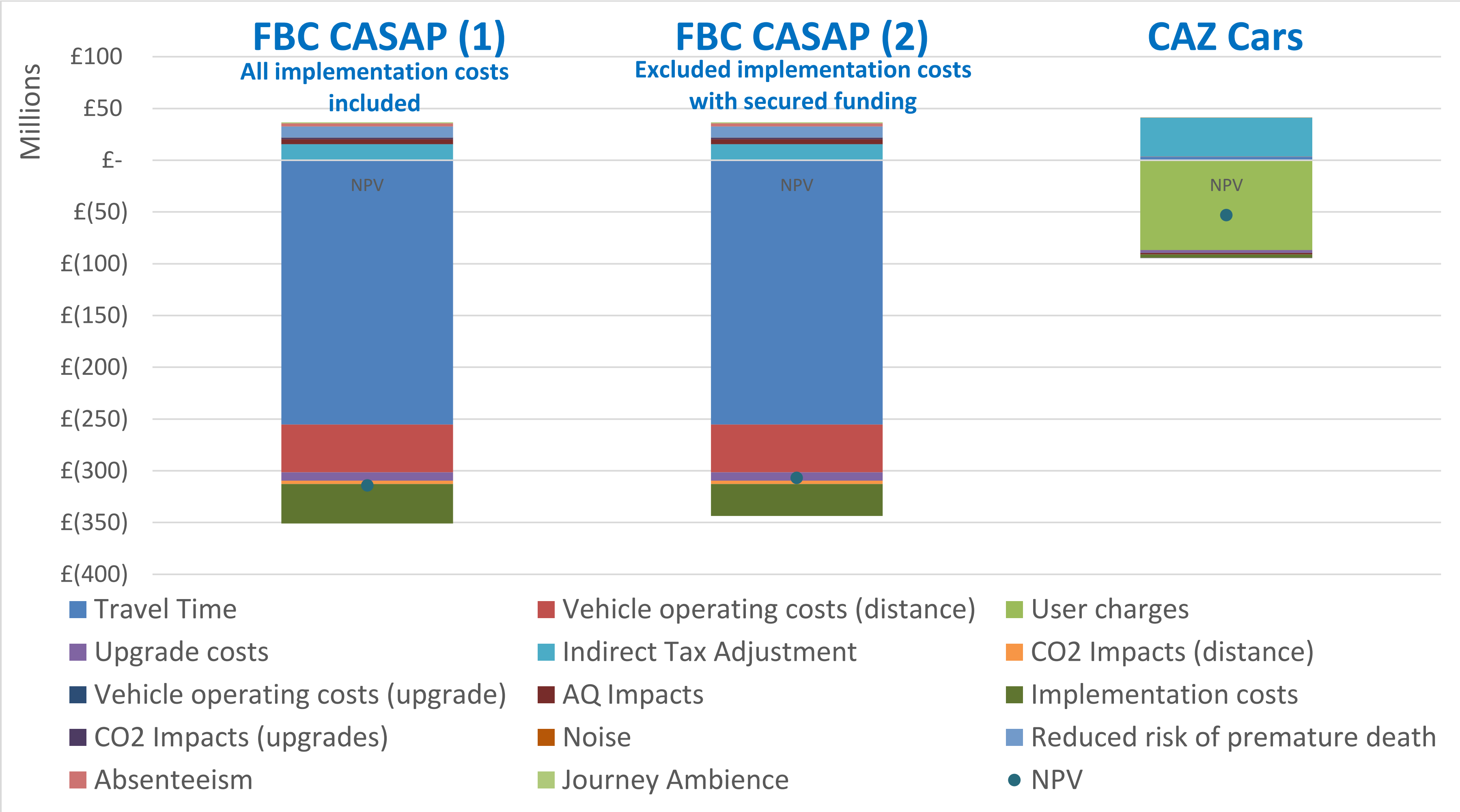
Impacts	Preferred Option		CAZ Cars
	All implementation costs included	Excluded costs with secured funding	-
Travel Time	-£255,412	-£255,412	£3,270
Vehicle operating costs (distance)	-£46,032	-£46,032	£299
User charges	£-	£-	-£86,762
Indirect Tax Adjustment	£15,557	£15,557	£37,589
CO_2 Impacts (distance)	-£3,405	-£3,405	£202
TUBA Partial NPV	-£289,292	-£289,292	-£45,401
Upgrade costs	-£7,973	-£7,973	-£2,473

[41] AECOM also carried out a 20-year appraisal threshold in order to take into account the potential life span of the cycle infrastructure. These results are not included in this document for consistencies.

Impacts	Preferred Option		CAZ Cars
	All implementation costs included	Excluded costs with secured funding	-
Vehicle operating costs (upgrade)	£7	£7	-£315
AQ Impacts	£4,861	£4,861	-£1,439
Implementation costs	-£38,138	-£30,799	-£3,279
CO_2 Impacts (upgrades)	£1,406	£1,406	£58
REE Partial NPV	-£39,837	-£32,498	-£7,564
Accidents	£118	£118	£[42]-
Noise	£8	£8	£-
Reduced risk of premature death	£10,861	£10,861	£-
Absenteeism	£2,995	£2,995	£-
Journey Ambience	£1,056	£1,056	£-
AECOM partial NPV	£15,038	£15,038	£-
TOTAL NPV	**-£314,091**	**-£306,752**	**-£52,965**

[42] It is assumed that there will be a change in the level of accidents as more people switch to active travel measures, however it is assumed that these impacts are captured in the 'user costs'

Figure 10 - PV of Impacts And NPV Of Option Scenarios



Note: Bars represent present value (PV) of impacts; dots represent aggregate net present value (NPV) of all impacts associated with CAZ option; all impacts are assessed relative to 'do nothing' baseline; all impacts presented in 2018 prices.

3.6.4 Results

CAZ TUBA Outputs

3.6.4.1 Travel times

The implementation of the Clean Air Zone results in a monetised travel time benefit of £3,270,417. The first order behavioural changes modelled in this scenario assume that a significant proportion of the vehicles that travel into the area either cancel their trip or avoid the charging area, this results in fewer vehicles on the road and improved travel times for the remaining vehicles. The monetised benefit of this reduced travel/congestion time is modelled here.

However, it is worth noting that the rerouting that occurs from avoid the charging area may result in congestion in other areas (and a time loss) therefore the overall net benefit shows us that the time saved from individuals cancelling their trip/avoid the city centre, is significantly greater than the additional congestion occurring beyond the charging area.

3.6.4.2 Vehicle operating costs (distance)

The increased mileage of vehicles attempting to avoid the CAZ and cancelling in response also impact the ongoing operational cost of the vehicles. The impact of this has a net benefit of £299,302. However, this does not include the operating cost benefit from vehicles that upgrade which is calculated separately.

3.6.4.3 Welfare costs

The welfare costs, which include the user charge for vehicles entering the clean air zone, and the disutility from vehicles that choose not to enter the charging zone, has a net cost of £86,762,293. This is the largest single impact across both options assessed and includes the daily £10 charge that non-compliant vehicles will be required to pay to enter the clean air zone as well as the utility cost to individuals who would have travelled in to the zone in the absence of a charging mechanism. The cost for individuals who no longer travel in to the charging zone is calculated by *rule of half* which assumes that lost utility is half the cost of the charge the enter the zone (£5) and applied for every day that a person would have otherwise travelled in to the area.

3.6.4.4 Indirect tax adjustments/revenue

The revenue received by the local authority is also assessed as a benefit. Here the indirect tax adjustments and revenue from the charging zone provide a benefit of £37,588,777. However, it should be noted that a significant proportion of this impact that is equal to the cost to individual drivers who enter the clean air zone, the cost of which is captured in the welfare costs, and so there is a netting out of the charging costs.

3.6.4.5 CO_2 impacts (distance)

The reduced travel time results in a reduction in the amount of CO_2 given off. This has a positive impact on the environment (and goes toward to UK governments greenhouse gas targets) resulting in a monetised benefit of £202,469.

CAZ Ricardo model outputs

3.6.4.6 Implementation costs

The implementation of the Clean Air Charging Zone is based on the infrastructure and personal needed to set it up and ensure that vehicles are compliant. The implementation cost is estimated at £3,278,752 This includes both the initial capital expenditure to set up to clean air zone and the ongoing operational expenditure over the 10-year appraisal period. Moreover, a 36% optimism bias is included in the cost of implementing the CAZ to account for any potential under costing for implementing such transport measures.

3.6.4.7 Upgrade Costs

The costs to individuals that choose to upgrade to a compliant vehicle is £2,473,138. This is based on the assumption that 17.6% of the 175,000 vehicles modelled will upgrade. The value represents the additional cost incurred through upgrading before individuals would have chosen to purchase a new vehicle had the CAZ not been introduced. The upgrade value is one of the most significant costs associated with the introduction of a CAZ and is the largest impact modelled in the Ricardo Economics Model.

The economics model assumes that everyone upgrades their vehicle the year that the CAZ is introduced (2021). Under the baseline, individuals are expected to upgrade at some point during the 10-year appraisal period. As a result, the upgrade cost is a net impact as people may upgrade when their current vehicle reaches the end of its lifespan in the baseline.

3.6.4.8 Fuel Costs (upgrade)

The change to the vehicle fleet has a resultant impact on the fuel consumed by the new fleet. The nature of the baseline fleet means that a proportion of the fleet will switch vehicles from a non-compliant Euro 4 and 5 Diesel vehicle to a compliant petrol Euro 4 and 5 petrol vehicle (with the rest upgrading to compliant diesel vehicles). While this has a positive impact on the air pollution, petrol vehicles are less fuel efficient than diesel cars and hence the total fuel consumed increases as a result. The total fuel consumption change has a net cost of £422,895.

3.6.4.9 Vehicle OPEX (upgrade)

The benefit associated with reduced vehicle OPEX is £107,769, which is due to the reduction in ongoing maintenance costs required for newer vehicles. The reduction in ongoing costs is expected to continue after the implementation of the Clean Air Zone until 2026, the assumed maximum lifetime that vehicles would have been on the road for before upgrading under the baseline. After 2026 it is assumed that all vehicles under a 'do nothing' scenario would have upgraded anyway and hence there is no net OPEX benefit.

3.6.4.10 CO_2 impact (upgrade)

The change in CO_2 is a direct result of the additional fuel consumption that occurs due to the fleet change and particularly the fuel change. The increased fuel used therefore has a further cost associated with the CO_2, the cost of which is £57,779. As discussed in the Fuel Costs, a proportion of non-compliant, Euro 4 and 5 diesel vehicles will switch to compliant, Euro 4 and 5 petrol vehicles. As petrol vehicles consume more fuel than diesel, it will result in more CO_2 being emitted, and hence a net cost overall.

3.6.4.11 Air Quality Impact

The change in air quality that results from the implementation of the Clean Air Zone has a net cost of £1,439,102. The emissions of both NO_x and $PM_{2.5}$ are shown to increase as a result of introducing the CAZ. While the increase in NO_x is greater than in $PM_{2.5}$, the cost associated (stemming from the health impact) is significantly greater for $PM_{2.5}$.

The increase in NOx is due to the small area of the charging zone compared to the larger Air Quality modelling area over which the air quality analysis is conducted. While it is expected that the air quality will improve within the CAZ boundary, the transport and air quality modelling also suggests that traffic will choose to travel around the CAZ area rather than through it. This results in an increase in NO_x emissions across the entire modelling area. Nevertheless, while this is a net cost, the change in emissions does not look at where the emissions levels are the most serious. The largest Air Quality Management Areas (AQMAs) is inside the CAZ boundary hence the implementation of the charging zone will likely go a long way to reducing the pollution concentration in this key area. Nevertheless, the modelled air quality area covers the rest of the city centre, hence raising pollution levels outside the CAZ boundary is still of concern given that it will still result in significant exposure to residents and visitors.

Preferred Options Results

TUBA Outputs

The CASAP package included a number of different measures, including restrictions on taxi licensing, upgrading local buses, active travel measures and city centre traffic managements schemes. These measures have their own cost and benefits associated, however the nature of TUBA is that results cannot be disaggregated to show the impacts of different measures hence we cannot know for certain where the costs and benefits reported below come from.

3.6.4.12 Travel times

The CASAP measures has a net travel time impact of -£255,412,231. The nature of specific road measures means that travel time is likely to increase in the short term while these measures are implemented, **however the potential congestion reduction in the long term is not modelled.** Moreover, the effects in the CASAP measures are dominated by the Westgate Street and Eastside schemes, which make it more difficult to access or traverse the city centre. These schemes apply to a significant number of vehicles in a congested area and so lead to increases in travel time and OPEX.

In contrast the active travel measures apply a relatively modest mode shift from car driver to trips with both an origin and destination in a defined area. In short, significantly more vehicles are affected by the changes to the layout in the city centre than removed from the demand matrices by way of the active travel measures.

It is important to remember however, a key limitation of the TUBA travel times as it only assumes that traffic redirects **rather than switching mode of transport.** In reality, we are likely to see a percentage of respondents switch to other means of transport which would likely reduce the time impact, as well as have a number of other knock on effects.

3.6.4.13 Vehicle operating costs (distance)

Given the increased travel time there is also an expected increased cost associated with the additional distance that vehicles will be driving. The monetised impact of this is -£46,032,340. This is likely to be due both to the impact of the additional measures themselves as well as additional driving in an attempted to avoid the measures.

3.6.4.14 Welfare costs

While there is a welfare loss associated with individuals being required to change their preferred route of travel, disutility is captured in the indirect tax adjustment.

3.6.4.15 Indirect tax adjustments/revenue

There is overall indirect tax benefit of £15,557,340 as a result of the various different CASAP measures introduced.

3.6.4.16 CO_2 impacts (distance)

The increase in overall journey time for individuals has an impact of the amount of CO2 emitted. The overall monetised impact from the additional CO_2 in the atmosphere as a result is -£3,404,932.

3.6.4.17 Active Travel Tool outputs

The increase in overall walking and cycling has a net benefit of £15,038,580. Reduced risk of premature death shows the highest benefits (£10,861,200), followed by absenteeism (£2,995,440), journey ambience (£1,056,020) and accidents (£118,060). Noise shows the lowest net benefit (£7,860). The results show the changes to Cardiff City Centre being implemented will provide significant economic benefits to cyclists along these routes. The overall result from the Active Travel Toolkit Assessment is shown in Appendix 2.

Ricardo Model Outputs

3.6.4.18 Implementation costs

The combined measures within the FBC CASAP package has a net cost of £38,138,203. The costs will vary across as summarised in **Error! Reference source not found.**. The nature and variety of the different measures involved in the CASAP approach results in a large net cost to implement them, the majority of which stems from the two city centre schemes. While the cost is significant, the traffic schemes are expected to bring a large benefit to the city centre once completed.

3.6.4.19 Upgrade Costs

Various measures within the CASAP package will generate fleet upgrades to buses and taxis to newer vehicles with lower emissions. While it has an environmental benefit, the upgrading that occurs has a net cost of -£7,972,573 to the bus and taxi fleet.

3.6.4.20 Operating Costs (fuel and opex)

There is a net operating benefit associated with the CASAP measures of £6,920. While the net benefit is relatively small. The associated fuel and operating costs are much more significant. The measures looked at result in an overall fuel cost saving of £1,416,730. The majority of this benefit comes from bus and taxis that upgrade to EVs and PHEV (although the new electricity cost is included). Moreover, the analysis assumes that under the baseline these vehicles upgrade to Euro VI, providing a more sustained economic benefit to the upgrade package.

Conversely, the measures result in an ongoing operation cost of £1,409,810. This is due to the assumption that newer vehicles are more expensive to maintain, counterbalancing the savings made through reduced fuel consumption

3.6.4.21 CO_2 reduction

Upgrading to new, more environmentally friendly vehicles also reduced the amount of CO_2 that the vehicles emit, this has a wider benefit of the society that can be monetised. This benefit is calculated at £1,405,811.

3.6.4.22 Air Quality Impact

The preferred package of measures significantly improve the overall air quality within Cardiff**. The overall emission reduction is given in**

Table 19. Here the benefit is monetised to account for the wider savings that occur due to reduced mortality and hospital admissions. **The benefit of the reduced emissions across the whole package is £4,860,916, which is much greater than the CAZ.**

Moreover, the vehicle and method of transport shift that occurs under the CASAP does not have the same 'baseline catch-up' observed under a CAZ. For example switches to cycling are not expected to happen in the baseline and buses and taxis that upgrade to EV's in the CASAP scenario, are only assumed to upgrade to Euro VI under the baseline, creating a more sustained benefit.

Finally, air quality impacts accounted for here demonstrate a real reduction in pollution and associated increased health standards, as opposed to the CAZ measure which has been shown to displace, rather than reduce emissions.

3.6.5 Economic Appraisal Summary

The nature and significance of the impacts associated with the FBC CASAP measures and the CAZ option vary substantially. Both schemes have a negative NPV, i.e. the costs outweigh the benefits, and the FBC CASAP has a larger negative NPV (£314,090,793 vs £52,951,224).

The source of the large negative NPV is different under the two measures. Under the Preferred Option (CASAP measures) the most significant proportion of the disbenefit comes from the additional travel time calculated in TUBA. Moreover, as TUBA is only modelled for a single year, it does not take in to account the demand response (assuming that people re-route, rather than change modes of transport) and congestion improvements expected at the culmination of the roadworks. This disbenefit is not a direct 'pocket' cost and the distributional analysis as detailed in Section 3.7 provides an assessment on the amount of time these increases will be which provides a more realistic understanding of the 'cost' of this disbenefit.

The largest impact affecting the CAZ measure is the user charges, while there is expected to be a large cost to the public, a proportion of whom will still wish to drive in to the city centre in non-compliant vehicles and pay the charge. Some of this cost is recuperated in an economic benefit which is captured elsewhere in the model.

Calculating the Net Present Value does not paint a full picture of the impacts of either scheme. There are likely to be dynamic responses to changes in congestion and new road measures introduced that cannot be accounted for. Moreover, it is important to recognise the inherent benefit that both measures reduce air pollution in line with targets. While the reduction in pollution is monetised to determine a benefit, **it is difficult to truly quantify the health benefit associated with reducing air pollution to 'acceptable' levels and beyond.** It is also important to note that while both measures reduce the level of pollution, the analysis of the CASAP measure shows that a real reduction in emission occur, with corollary health benefits.

The air quality assessment shows that the CAZ measure just moves the pollution from within the CAZ area to outside, potentially negating any health benefits that are realised from achieving compliance on Castle Street. This is highlighted in the net cost to CAZ air pollution reported in the results.

Moreover, there is also a broader concern about the ability to accurately model a package that combines several different measures, as attempted in the CASAP. The interaction of different measures, such as the increased congestion from the city centre schemes and the introduction of new cycleways under the active travel measure, will have behavioural affects that cannot be modelled individually. These are likely to result in additional changes in travel patterns, potentially increasing the number of individual's taking up active travel and public transport, above those achieved by the independent introduction of the cycle way. It is difficult however to truly know the long term impacts of these different measures interacting.

It is also worth discussing who, the different measures will affect the most. The key response to the CAZ measure is that it will require people to purchase a new vehicle in order to avoid paying the charge. This will likely disproportionally affect the poorest amongst the community who currently have the greatest percentage of non compliant vehicles and may not be able to afford to purchase a compliant vehicle. This is explored in more detail in the distribution analyses in Section 3.7. Moreover, for those who cannot afford to purchase a new vehicle and who may be forced to pay the charge, the fine will be a significantly larger proportion of their disposable income than for more affluent people who can afford to pay/upgrade their car.

Under the CASAP measures, bus companies and taxi drivers are required to purchase compliant vehicles. While less directly correlated this may also have a disproportionate impact on the poorest, who disproportionately take the bus (and whose fares may get raised, particularly from the private operator). Moreover, taxi drivers, are also one of the lowest paid professions. Divers will have to purchase a new, compliant, vehicle, many of whom, may not be able to afford to. For a more detailed discussion of these impacts, see the distributional impact assessment.

3.7 Distributional Impact Analysis

Distributional Impact Analysis (DIA) analysis inherently relies on other areas of the modelling undertaken to support the assessment of the preferred option and CAZ benchmark., specifically the transport and air quality modelling undertaken by Mott Macdonald and Ricardo respectively. The full DIA methodology was produced by Ricardo, and in the Distributional Analysis Results Methodology Report, ED 11182, included in Appendix

This section provides a summary of the DIA around the Clean Air Zone Option 1 (CAZ 1) and the revised package of Clean Air Strategy Action Plan measures (FBC-CASAP), and presents the key issues. Unlike cost-benefit analysis, which assesses the impacts associated with the options in an aggregate way using average values, distributional analysis seeks to understand whether there are any specific patterns in the distribution of the impacts, and to explore whether any option unduly favours or disadvantages a particular group. This can inform measures to mitigate the impact of the policy on those groups or amendment of the policy itself

Six socioeconomic impact groups, as defined by JAQU guidance, have been analysed in this distributional analysis and ranked as quintiles, with **the first quintile meaning the lowest 20%** and the **fifth quintile the highest 20%** of the population. The quintile ranking was based on the whole of Wales or England and Wales, depending on the variable (see Table 22). In addition, IMD category, used as reference for the income, has also been evaluated in relation to the study area only (DA Domain). All the socioeconomic impact groups are summarised as follows:

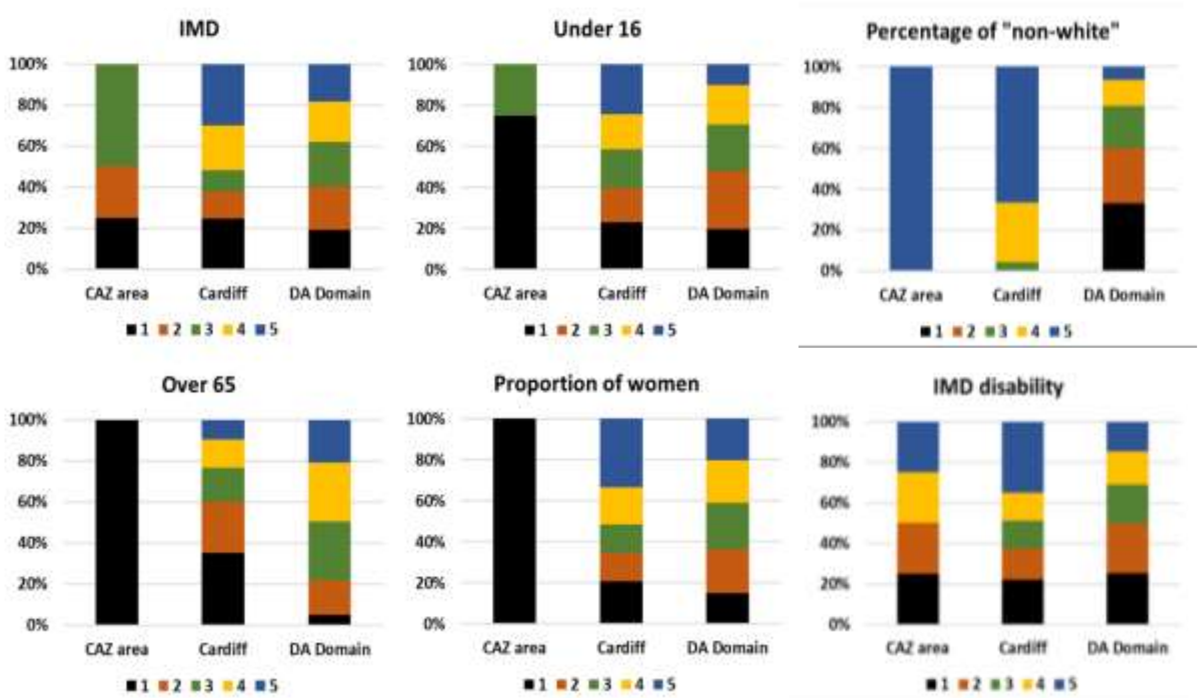
Table 22 - Socioeconomic Impact Groups

Socioeconomic group	Domain of study for quintile calculations	Quintile 1 reference	Quintile 5 reference
Income (referred to as IMD)	DA Domain Wales	Most deprived population	Least deprived population
Under 16 (referred to as Children)	England and Wales	Lowest proportion of under 16 in the population	Highest proportion of under 16 in the population
Over 65 (referred to as Elderly)	England and Wales	Lowest proportion of over 65 in the population (at LSOA level)	Highest proportion of under 65 in the population (at LSOA level)
Proportion of women (referred to as women)	England and Wales	Lowest proportion of women in the population (at LSOA level)	Highest proportion of women in the population (at LSOA level)
Percentage of "non-white" (referred to as Ethnicity)	England and Wales	Lowest proportion of "non-white" in the population (at LSOA level)	Highest proportion of "non-white" in the population (at LSOA level)
IMD disability (referred to as disability)	Wales	Lowest ratio of population with disability in the population (at LSOA level)	Highest ratio of population with disability in the population (at LSOA level)

The quintile distribution for each impact group living within each of the assessment domains (DA Domain, AQ modelling domain and charging scheme areas) is summarised in Figure 11. Some of the key points from these charts can be summarised as follows:

- The city centre area (within the Charging Scheme boundary) has the highest proportion of low income families (only the first three quintiles of deprivation are found in this area), the lowest proportion of children under 16 and adults over 65. As such improvements in air quality in this area will have greater benefits for these lower income groups groups.
- Conversely the wider DA Domain the distribution among the different socioeconomic group is fairly distributed.
- The city centre also seems to have only the highest quintile of "non-white" population and lowest quintile of "women". But only 4 LSOAs are included within this area.
- More generally the distribution of these socioeconomic groups is more even outside the centre and in the DA Domain.

Figure 11 - Relative Percentage Of Quintiles For Each Geographical Zones And Demographic Groups. The Total Number of Lsoas within the Different Zones Are As Follows: 4 (CAZ Area); 210 (Cardiff With CAZ Area Excluded); 1129 (DA Domain With Cardiff Excluded)



Implicitly, the distributional analysis of the impacts considers the full lifetime over which they are due to be experienced. For some impacts, the focus of this assessment is on target year (e.g. air quality). This is because the assessment is limited due to the modelling available (e.g. outputs of the AQ model are only available for a limited number of years, and certainly not for the full appraisal period considered in the core CBA). However, the first year of the CAZ is also when CAZ impacts are expected to be greatest – hence this focus is useful to highlight the point at which most extreme distributional impacts are anticipated. Also, the further into the future the appraisal goes, the greater the uncertainty regarding both the impacts assessed, but also the distribution of the demographic groups within society.

The screening step was undertaken with reference to the list of impacts detailed in the Webtag A4.2. Impacts were 'screened in' (i.e. for inclusion in the distributional analysis) or 'screened out' (i.e. excluded) taking into account the likely local issues of the proposed options. On the basis of the screening, the following effects have been 'screened-in':

1. Air quality - changes in concentrations of NO_2
2. Affordability – including user benefits, considering residents
3. Traffic impacts –accessibility impacts through changes in journey times.

3.7.1 Appraisal Methodology

The approach to appraising each of the impacts closely follows the methodology set out in the JAQU and supporting WebTAG guidance. Namely, the 'impact variables' (describing how the impacts vary or are distributed across a geographic area) are overlaid with the 'grouping variables' (describing how different societal groups are distributed across the same area).

In most cases the appraisal is then made on the basis of splitting both the grouping and impact variables into quintiles, and then judging whether the impact on a given population group is proportionate to the representation of that group in the wider population (this type of analysis is referred to as 'quintile analysis' throughout this document). Not all of the impacts need to be appraised for each grouping variable. **Error! Reference source not found.** indicates the impacts that should be appraised for each group.[43]

Group	Air Quality	Affordability	Traffic impacts
Deprivation / income	✓	✓	✓
Children	✓		✓
Old people			✓
Disability			✓
Sex			✓
Ethnicity			✓

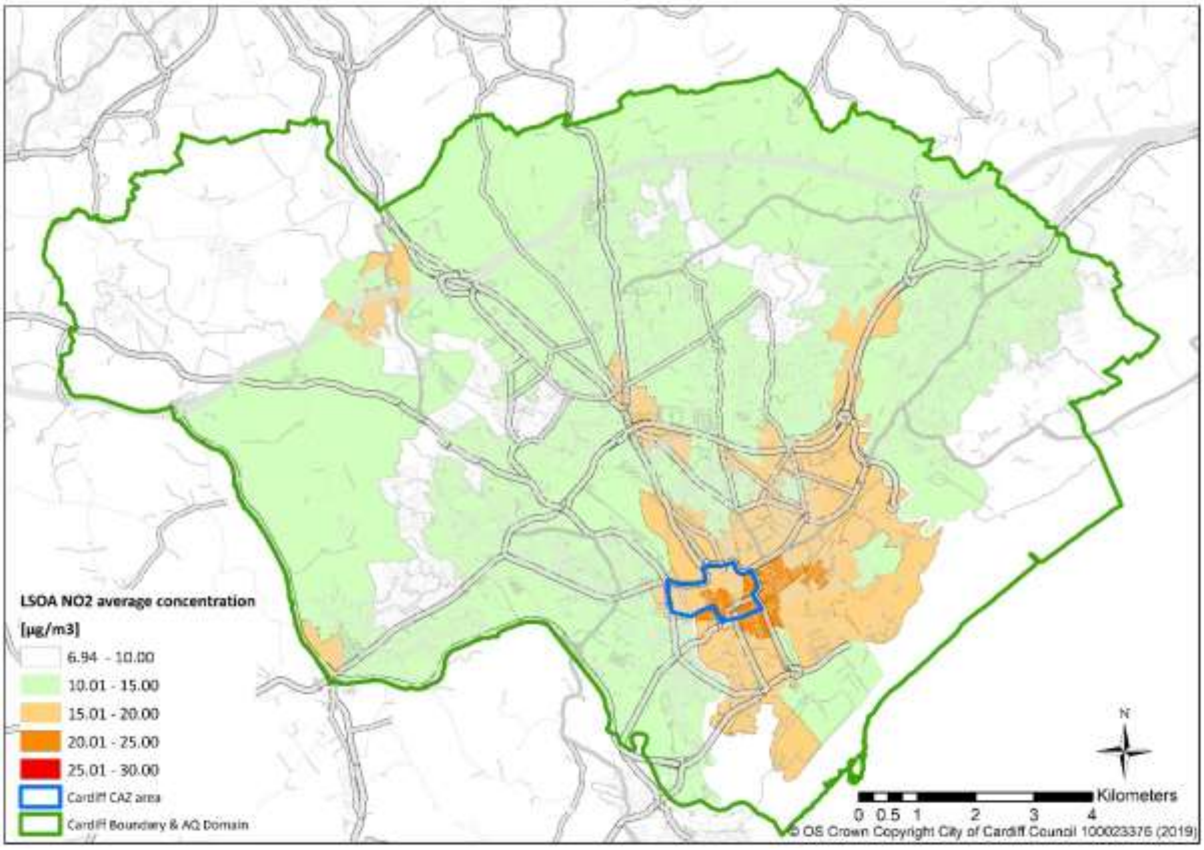
The overlay of impacts and groups was then undertaken on a Lower Layer Super Output Area (LSOA) basis.

3.7.2 Air Quality

The Air Quality model carried out to evaluate the scenarios modelled the annual mean NO_2 concentrations across Cardiff, for modelling year 2021. All analysis presented here was undertaken on the model outputs for year 2021. All impacts are presented as a change relative to the baseline 2021 scenario. Only analysis regarding changes in NO_2 concentrations is presented in this section. Figure 12 shows high zones of concentration located in the city centre, for the modelled 2021 Baseline scenario. The highest NO_2 concentrations are mostly found in the city centre and the eastern area outside the centre.

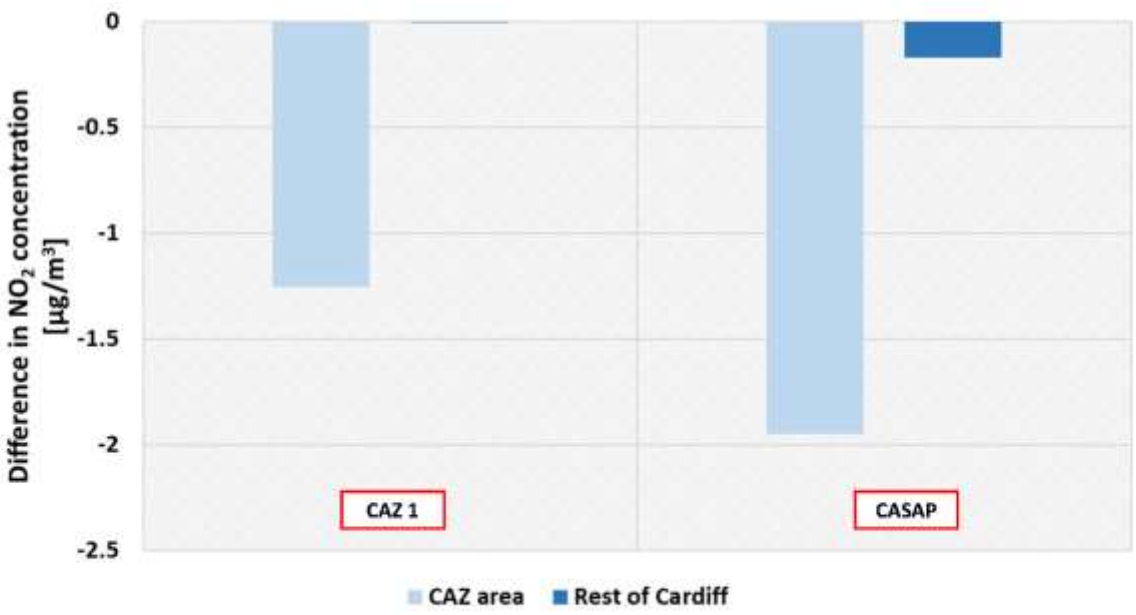
[43] Summary results also for available for air quality impacts for old, disability, sex, ethnicity and elderlies, but these are not as detailed as for the children and income groups.

Figure 12 - Baseline 2021 NO2 concentration at LSOA level for the AQ Domain (Cardiff)



The results of this analysis are summarised in below for each of our two analysis zones. This shows that the CASAP scenario has an overall stronger reduction in NO_2 concentration in comparison with the CAZ 1 scenario. Even within the charging scheme area, the CAZ 1 would appear not to be as effective as the CASAP option.

Figure 13 - Difference in average NO2 concentration (in µg/m3) between the modelled CAZ 1 and CASAP scenarios and the Baseline 2021 for two different geographical zones.



The strongest air quality improvement is found within and near the CAZ area (especially North of the CAZ), for both scenarios. As previously discussed, the CASAP shows a stronger decrease in NO_2 concentration in the centre. In both scenarios, an increase in air pollution would occur in the northern part of the city, and this is more pronounced for the CAZ 1 scenario.

The greater improvement with the CASAP scenario could be due to the city-wide measures included in this scenario, namely bus and taxi fleet upgrade schemes. The traffic management schemes in the city centre also included in CASAP explain the stronger decrease in NO_2 concentrations modelled in the CAZ area.

Figure 14 - Absolute Difference in NO2 Concentrations (In Mg/M3) Averaged At LSOA, Between the CAZ 1 and Baseline Scenario

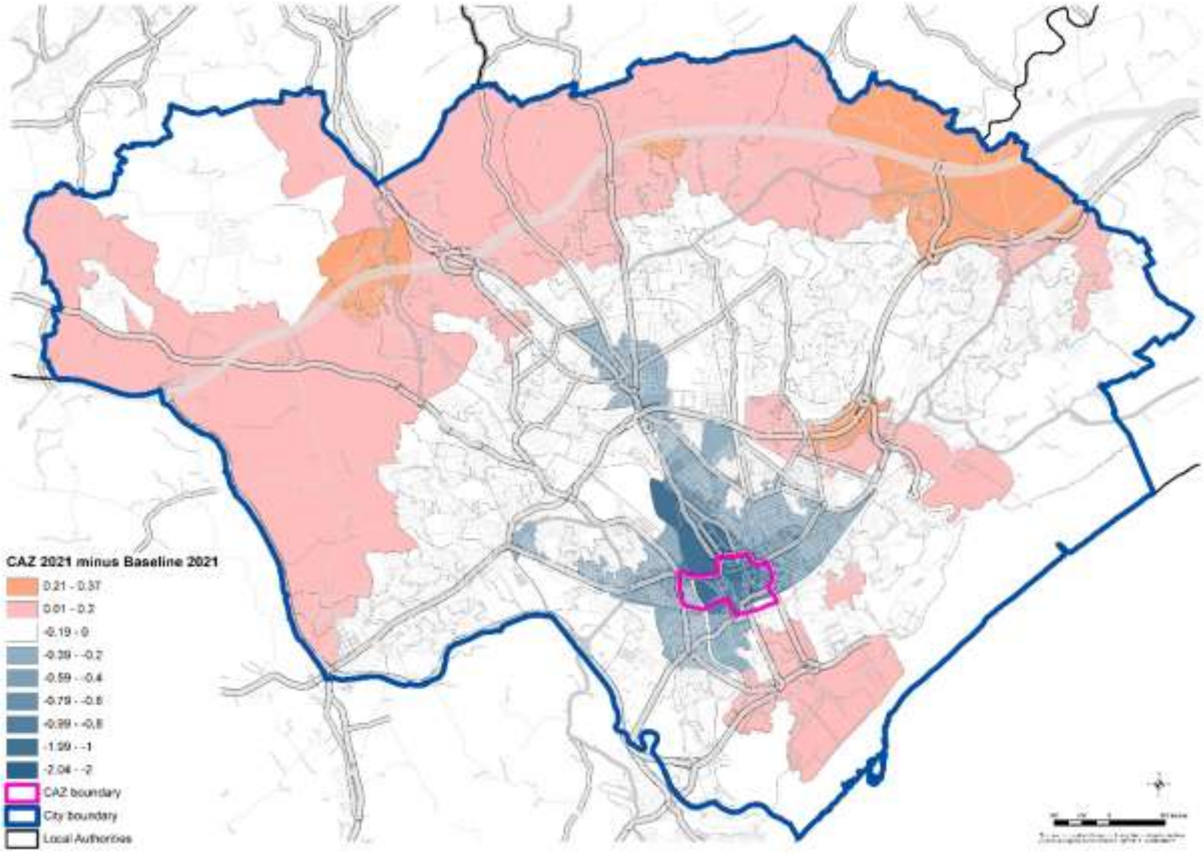
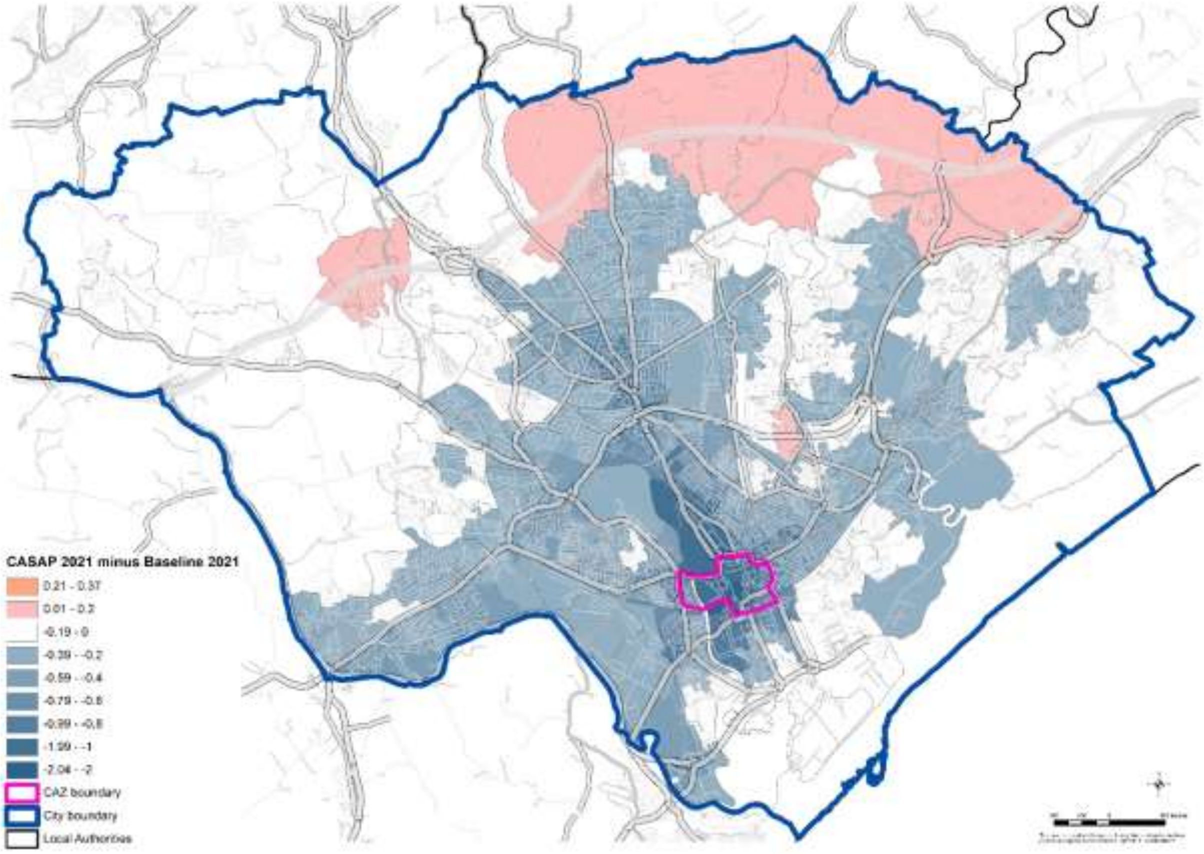


Figure 15 - Absolute Difference in NO2 concentrations (in µg/m3) averaged at LSOA, between the Preferred Option and baseline scenario



3.7.2.1 Socioeconomic Quintile Analysis

The following analysis explores the distribution of average NO_2 concentrations on socioeconomic impact groups, with a focus on low income groups (WIMD) and children under 16.

Table 23 - Modelled NO2 Concentration Differentiated By IMD Quintile (Reference Whole Model Domain) For the Baseline, the CAZ 1 and Preferred Option Scenarios

Option	Income IMD Quintile domain	Most deprived ← 1	2	3	4	→ Least deprived 5
2021 BASELINE	Average NO_2 concentration (µg/m^3)	13.00	13.50	14.30	13.40	11.81
2021 CAZ 1	Average NO_2 concentration (µg/m^3)	12.87	13.35	14.09	13.29	11.80
	Absolute difference in NO_2 concentration to baseline (µg/m^3)	-0.13	-0.15	-0.22	-0.11	-0.01
	Relative difference in NO_2 concentration to baseline (%)	-1.02	-1.12	-1.51	-0.83	-0.08
2021 CASAP	Average NO_2 concentration (µg/m^3)	12.67	13.18	13.81	13.06	11.59
	Absolute difference in NO_2 concentration to baseline (µg/m^3)	-0.33	-0.32	-0.49	-0.34	-0.22
	Relative difference in NO_2 concentration to baseline (%)	-2.54	-2.36	-3.42	-2.55	-1.90

Table 24 - Modelled NO2 Concentration Differentiated By "Under 16s" Quintile for the Baseline and All the Scenarios

Option	Under 16 (quintile)	Lowest proportion 1	2	3	4	Highest proportion 5
2021 BASELINE	Average NO_2 ($\mu g/m^3$)	14.92	12.81	11.94	12.81	11.90
2021 CAZ 1	Average NO_2 concentration ($\mu g/m^3$)	14.70	12.75	11.92	12.69	11.83
	Absolute difference in NO_2 concentration to baseline ($\mu g/m^3$)	-0.22	-0.06	-0.02	-0.11	-0.07
	Relative difference in NO_2 concentration to baseline (%)	-1.48	-0.48	-0.21	-0.89	-0.60
2021 CASAP	Average NO_2 concentration ($\mu g/m^3$)	14.44	12.53	11.74	12.48	11.62
	Absolute difference in NO_2 concentration to BASELINE ($\mu g/m^3$)	-0.47	-0.28	-0.20	-0.32	-0.28
	Relative difference in NO_2 concentration to BASELINE (%)	-3.17	-2.17	-1.68	-2.52	-2.37

For the baseline situation the analysis shows that concentration of NO_2 are lowest for the highest income groups indicating that these groups tend to live in areas with less traffic and congestion. Therefore, there is a clear existing inequality in the burden of air pollution in Cardiff when looking through the lens of income distribution. In addition, in the baseline, the areas with the lowest proportion of children have the highest levels of pollution.

The implementation of a CAZ 1 scheme will have a lower impact in terms of air quality (NO_2 concentrations) than the CASAP scenario. With the CAZ 1 scenario, all the quintiles for income and children will see on average a decrease in NO_2 concentrations, with the greatest improvement found for the middle income (quintile 3) and the areas with the lowest population of children.

With the implementation of the CASAP scenario, the distribution for both income and under 16 groups is similar but with a stronger decrease in NO_2 concentrations.

An alternative view of the data is seen by counting the number of LSOAs experiencing an improvement or a deterioration of air quality in terms of NO_2 and this is shown in Table 25 and Table 26 below.

The charging scheme improves air quality for the majority of the population within Cardiff, but a non-negligible part of the population will see its air quality deteriorate, mainly for the least deprived population). This is most probably due to the diverting traffic increasing concentrations around the charging zone. In terms of the impact of the CASAP scenario on income quintiles the picture is similar to when considering average concentrations. The greatest benefit is for low income areas and the smallest benefit is for high income areas. In relation to children under 16 the picture is more complex. Both those in the highest and lowest quintiles have the greatest number of areas showing an improvement.

The impact of a CASAP scenario will be of higher benefit in terms of air quality improvement, in comparison with a CAZ 1 scenario.

Table 25 - Number of LSOAs and population with an improvement or a deterioration of NO2 concentration (relative to baseline), disaggregated by IMD quintile (reference whole model domain) for the domain of study

Option	Income IMD Quintile domain	Most deprived ← 1	2	3	4	Least deprived → 5
CAZ 1	Number of LSOAs with improved air quality	47	26	20	22	34
	Population with improved air quality	79,608	47,137	35,831	38,246	54,789
	Number of LSOAs with a worsening of air quality	1	0	2	2	24
	Population with a worsening of air quality	1,838	0	3,038	3,584	38,686
CASAP	Number of LSOAs with improved air quality	59	26	27	36	56
	Population with improved air quality	99,833	47,137	46,670	61,496	89,136
	Number of LSOAs with a worsening of air quality	0	0	0	0	10
	Population with a worsening of air quality	0	0	0	0	17,196

Table 26 - Number of LSOAs and population with an improvement or a deterioration of NO2 concentration (relative to baseline), disaggregated by "Under 16" quintile for the domain of study

Option	Under 16 Quintile domain	Lowest proportion ← 1	2	3	4	Highest proportion → 5
CAZ 1	Number of LSOAs with improved air quality	33	24	23	27	42
	Population with improved air quality	63,483	38,399	37,178	44,126	72,425
	Number of LSOAs with a worsening of air quality	4	8	12	3	2
	Population with a worsening of air quality	6,434	12,233	19,344	5,598	3,537
CASAP	Number of LSOAs with improved air quality	50	33	38	34	49
	Population with improved air quality	90,304	51,949	61,366	56,151	84,502
	Number of LSOAs with a worsening of air quality	1	2	3	2	2
	Population with a worsening of air quality	1,985	3,257	4,770	3,647	3,537

3.7.2.2 Quintile Analysis

The overlay of the impact and demographic variables following the Webtag guidance for IMD is presented in Table 27 and for the "under 16" category in Table 28, for the CAZ 1 scenario and Table 29 and

Table 30 for the Preferred Option of CASAP measures.

Table 27 - Webtag 'quintile' analysis for CAZ 1 – WIMD overlay with air quality

Income IMD CAZ 1	Most deprived ← 0%-20% 1	20%-40% 2	40%-60% 3	60%-80% 4	Least deprived → 80%-100% 5	Total
Population with improved air quality	93,156	47,137	43,632	50,379	64,149	235,438
Population with no changes[44]	0	0	0	0	0	
Population with deteriorating air quality	6,677	0	3,038	11,117	42,183	
Net winners/losers	86,479	47,137	40,594	39,262	21,966	
Total number of winners across all groups						
Net winners/losers in each area	36.73%	20.02%	17.24%	16.68%	9.33%	
Share of the total population in the impact area	27.62%	13.04%	12.91%	17.01%	29.42%	
Assessment	✓✓✓	✓✓✓	✓✓	✓✓	✓	

Table 28 - Webtag 'quintile' analysis for CAZ 1 – Children overlay with air quality

Under 16 CAZ 1	Lower proportion ← 0%-20% 1	20%-40% 2	40%-60% 3	60%-80% 4	Higher proportion → 80%-100% 5	Total
Population with improved air quality	78,746	39,819	46,792	52,255	80,841	235,438
Population with no changes[45]	0	0	0	0	0	
Population with deteriorating air quality	13,543	15,387	19,344	7,543	7,198	
Net winners/losers	65,203	24,432	27,448	44,712	73,643	
Total number of winners across all groups						
Net winners/losers in each area	27.69%	10.38%	11.66%	18.99%	31.28%	
Share of the total population in the impact area	25.53%	15.27%	18.30%	16.54%	24.36%	

[44] For this category it has been assumed a difference in NO_2 concentration between the modelled CAZ scenario and the baseline to be 0.

[45] For this category it has been assumed a difference in NO_2 concentration between the modelled CAZ scenario and the baseline to be 0.

Assessment	✓✓	✓	✓	✓✓	✓✓✓	

Table 29 - Webtag 'quintile' analysis for Preferred Option– WIMD overlay with air quality

Income IMD CASAP	Most deprived ← 0%-20% 1	20%-40% 2	40%-60% 3	60%-80% 4	Least deprived → 80%-100% 5	Total
Population with improved air quality	99,833	47,137	46,670	61,496	89,136	
Population with no changes[46]	0	0	0	0	0	
Population with deteriorating air quality	0	0	0	0	17,196	
Net winners/losers	99,833	47,137	46,670	61,496	71,940	
Total number of winners across all groups						327,076
Net winners/losers in each area	30.52%	14.41%	14.27%	18.80%	21.99%	
Share of the total population in the impact area	27.62%	13.04%	12.91%	17.01%	29.42%	
Assessment	✓✓	✓✓	✓✓	✓✓	✓	

Table 30 - Webtag 'quintile' analysis for Preferred Option– Children overlay with air quality

Under 16 CASAP	Lower proportion ← 0%-20% 1	20%-40% 2	40%-60% 3	60%-80% 4	Higher proportion → 80%-100% 5	Total
Population with improved air quality	90,304	51,949	61,366	56,151	84,502	
Population with no changes[47]	0	0	0	0	0	
Population with deteriorating air quality	1,985	3,257	4,770	3,647	3,537	
Net winners/losers	88,319	48,692	56,596	52,504	80,965	
Total number of winners across all groups						327,076
Net winners/losers in each area	27.00%	14.89%	17.30%	16.05%	24.75%	
Share of the total population in the impact area	25.53%	15.27%	18.30%	16.54%	24.36%	
Assessment	✓✓	✓✓	✓✓	✓✓	✓✓	

[46] For this category it has been assumed a difference in NO_2 concentration between the modelled CAZ scenario and the baseline to be 0.

[47] For this category it has been assumed a difference in NO_2 concentration between the modelled CAZ scenario and the baseline to be 0.

The implementation of a CASAP scenario would not lead to a socioeconomic group with a "Large beneficial" impact. However the reason for this is only because there is a lower proportion of population that would see a worsening of air quality. Overall, for both the income and under 16 groups, and almost all quintiles, the overall assessment is defined as "moderate beneficial". Only the least deprived population is considered as "slight beneficial", as only this category as some people would have an increase in NO_2 concentrations

3.7.2.3 Air Quality Summary

The geographical distribution of changes in NO_2 concentrations show a similar distribution between the options. In simple terms both scenarios will lead to an overall improvement in air quality, but this is more pronounced with the preferred CASAP option than CAZ 1. The strongest decrease is expected to be located in the city centre, but a small deterioration would occur in the northern part of the city.

The analysis in relation to demographic data at the LSOA level reflects this basic picture and allows an assessment of the distribution of impacts for key socioeconomic groups (primarily IMD and children under 16). Again, the distribution appears to be similar with the CASAP and CAZ 1 options, but with a stronger effect for the CASAP scenario.

That said, the most deprived part of the population as well as the population with the highest proportion of children (representative of the residents inside the CAZ area and the city centre to some extent) would have the most air quality improvement with both scenarios.

Table 31 - Summary of air quality distributional impacts

Scenario	Summary assessment
CAZ 1	✓ • All LSOAs see improvement in air quality concentrations, hence quintile analysis shows no distributional impact. • A stronger benefit is found for areas with the lowest income. However, the highest income would be disadvantaged. • Option achieves on average reduction at all sensitive receptors
CASAP	✓✓ • All LSOAs see improvement in air quality concentrations, hence quintile analysis shows no distributional impact • A stronger benefit is found for areas with the lowest income • Option achieves on average reduction at all sensitive receptors

3.7.3 Affordability for Households

A charging scheme will directly affect households with cars that do not comply with the CAZ standard and so would be subject to a charge or the cost of upgrading their vehicle. Therefore, low income groups could be more impacted as they are more likely to own older non-compliant vehicles as detailed in Table 32. This result matches evidence from the literature: studies[48] note that in general, there is a negative relationship between car age and household income (i.e. older cars tend to be owned by poorer households).

[48] See for example: http://economics.ca/2009/papers/0455.pdf

Table 32 - % of cars non-compliant split by IMD quintile

IMD quintile	1	2	3	4	5
% cars owned by households in quintile which are NC	50.0	48.5	47.8	48.6	42.9

However analysis shows that the highest number of estimated non-compliant trips are performed by (and hence the costs of the CAZ scheme fall greatest upon) the **least deprived population** (quintile 5 of IMD). Costs then decrease for the remaining quintiles. Despite that a greater proportion of non-compliant vehicles are owned by poorer population as detailed above. The costs likely to be more important for the richer population, as they make more trips to the CAZ.

The Webtag "quintile" analysis as detailed in Table 33 again that the least deprived quintile of the population is likely to suffer the most from a CAZ 1. However, given some level of costs fall on all LSOAs in the scope of the DA Domain (i.e. all LSOAs have some non-compliant vehicles and some trips to the CAZ), all LSOAs (and hence all their residents) fall within the 'losers' category. The assessment presented corresponds to the "Moderate Adverse" group for each quintile. No assessment is presented for the other options given these options will not have direct effects on households in the same way as the impacts analysed here.

Table 33 - Webtag 'Quintile' Analysis For CAZ 1 – IMD Overlay with "Number Of Trips With Non-Compliant Cars

Income IMD CAZ 1	Most deprived ← 0%-20% 1	20%-40% 2	40%-60% 3	60%-80% 4	Least deprived → 80%-100% 5	Total
Number of population non driving non-compliant cars to the CAZ	0	0	0	0	0	
Number of population driving non-compliant cars to the CAZ	1,737	1,562	1,536	2,172	3,511	
Net winners/losers	-1,737	-1,562	-1,536	-2,172	-3,511	
Total number of winners across all groups						-10,517
Net winners/losers in each area	-16.52%	-14.85%	-14.60%	-20.66%	-33.38%	
Share of the total population in the impact area	16.52%	14.85%	14.60%	20.66%	33.38%	
Assessment	X X	X X	X X	X X	X X	

3.7.3.1 Affordability Summary

The WebTAG quintile analysis illustrates that some level of cost will fall on all LSOAs, and hence on all groups in society. Looking in more detail at the size of the impacts, the analysis of number of non-compliant trips into the CAZ suggests the direct impacts of the CAZ 1 will fall greatest on:

- the least deprived population quintile 5 of IMD
- highest ratio of persons with disabilities
- highest ratio of "non-white" people

Given all trips from those LSOAs located within the CAZ will be captured by the charging zone, the groups which experience greater effects mirrors those demographic groups which make up a greater proportion of the population living in Cardiff city centre. In addition, poorer households tend to own older, and more likely a non-compliant car.

These direct impacts for the CAZ 1 compare with the indirect impacts through change in travel times experienced with the CASAP scenario. These impacts have the potential to be progressive in nature if their journeys are directly impacted by the scheme and as a result suffer increased travel times, route changes or opt to change mode.

However, given uncertainty around these effects and the likely magnitude of the direct impacts under a CAZ 1, the CAZ 1 option is assessed as having the most negative impact in terms of household affordability.

Table 34 - Summary of household affordability distributional impacts

Scenario	Summary assessment
Preferred Option	× • No direct impacts on households given cars not included in scope • Will be indirect impacts on households if their journeys suffer increased travel times, route changes or opt to change mode.
CAZ 1	×× • Webtag quintile analysis illustrates that some level of cost will fall on all LSOAs, and hence on all groups in society. • Looking in more detail, analysis suggests direct impacts will fall greatest on: least deprived population (quintile 5 of IMD), lowest proportion of under 16s (i.e. LSOAs with a rather old adult demographic) and lowest ratio of "non-white" people. • No distributional impact

3.7.4 Accessibility - Travel Times

Modelled travel times data for both options (CAZ 1 and CASAP) was provided by Mott MacDonald as an output of their transport model. The data shows the average travel time in minutes from each origin transport model zone to all other zones within the transport model.

In order to best represent the changes in travel times for both scenarios, a model zone within the CAZ area has been selected to represent traffic flow changes for both scenarios. It also includes the St. David's carpark, a key amenity within the CAZ area. However, as CASAP included traffic schemes at different places, the results could differ with another zone.

For this study, the travel times for commuting cars during the AM period were considered as representative of the traffic accessibility and it would show the largest changes in travel time in relation to household accessibility. Absolute (in mins) and relative (in %) changes in travel times from a zone within the DA domain and the zone in the centre between both scenarios were calculated.

The results in **Table** 35 and Table 36 illustrate the effects on travel time change for both scenarios to the city centre.

Table 35 - Absolute Change In Travel Times (In Minutes) Defined By Percentage Of Transport Model Zones Of Origin

Range of impacts (minutes)	CASAP	CAZ 1
<-10	0.00%	0.00%
-10 to -5	0.00%	0.00%
-5 to -3	0.00%	0.00%
-3 to 0	1.52%	96.19%
0 to 3	42.87%	3.81%
3 to 5	31.66%	0.00%
5 to 10	22.85%	0.00%
>10	1.09%	0.00%

Table 36 - Relative Change In Travel Times (In %) Defined By Percentage Of Transport Model Zones Of Origin

Range of impacts (%)	CASAP	CAZ 1
<-16%	0.00%	0.00%
-16% to -6%	0.11%	0.00%
-6% to -2%	0.54%	6.20%
--2% to 2%	2.18%	93.80%
2% to 6%	22.20%	0.00%
6% to 16%	47.88%	0.00%
>16%	27.09%	0.00%

With the implementation of a CAZ 1, all changes in travel times are within 3 minutes (either positive or negative), and therefore not likely to be perceived by the population and the overall impact is considered to be "neutral".

For the Preferred Option (CASAP) scenario, there is a potential for around 30% of "zones" which on average will experience an increase in travel times by 16%. However, it should be noted that nearly 75% of the journeys would only increase by 0-5 minutes, and only 1% increase by more than over 10 minutes. However, this scenario is considered to have an adverse impact in terms of travel time on the population.

The assessment of the traffic accessibility for the CAZ 1 and CASAP scenario is summarised as follows:

Table 37: Summary of traffic accessibility distributional impacts

Scenario	Summary assessment
CAZ 1	- • No significant impacts could be identified
CASAP	X • The area in the north west of the city centre could experience an increase in travel times by more than 10 minutes. In those areas live the least deprived population with a low ratio of children

3.7.5 DIA Conclusions

The analysis has explored how the benefits and costs are distributed for the two options under consideration in Cardiff: the preferred option CASAP scheme and the CAZ scheme. The distribution of impacts have been looked at under three categories: air quality, household affordability and traffic impacts. The key findings against each of these categories are set out below:

Air Quality

- CAZ 1 and CASAP overall have an air quality benefit for most LSOAs with the greatest benefit within the charging zone and the city centre and some small dis-benefits outside. These benefits are not distributed evenly and there is a clear trend with both income and households with children under 16. Low income households are seeing the greatest benefit and higher income households the least benefit. In terms of children those households with the least children are seeing the greatest benefit and those with the most the least benefit. These both correspond with the characteristics of households within the charging zone. A CASAP scenario leads to an overall greater benefit for the population in the Cardiff than a CAZ 1.
- When looking at sensitivity receptors, for the charging scheme and CASAP, all categories of receptors on average see an air quality improvement, with the greatest improvement being from the CASAP scenario and within the charging zone and the city centre. Those that benefit most are educational residences and communal residences.

Household affordability

- The CASAP scenario that includes traffic management schemes may generate a small direct impact on households in relation to journeys that could be affected by the scheme either by diversion or changing mode. There may also be a small indirect impact through affects to business, primarily relating to deliveries. However, no specific distributional impact between different social groups is expected.
- The charging scheme will have a direct impact on households with non-compliant vehicles.

  The analysis of trips to the CAZ area with non-compliant cars indicate that the least deprived population would be the most impacted. In addition, as low income population tends to own more non-compliant vehicles, they could also directly suffer from the charging scheme.

Traffic accessibility

- A charging scheme would not lead to significant changes in travel times
- The North west region outside of the city centre could see travel times increase by more than 10 minutes (for a 15 minutes average travel time) when going to the city centre with a CASAP scenario. This is probably due to the traffic management schemes (mostly east side) that will redirect the traffic to Cardiff street (A4119). In those areas, the analysis at LSOA level indicates a population with higher income and with a low proportion of children.

Both schemes solve the compliance issue on Castle Street and generate broad air quality benefits across the city. However these benefits are more pronounced with the CASAP scenario than CAZ 1. In addition, a charging scheme will lead to much greater costs to households due to the direct and indirect impact of the charges. Whist the higher income population seems to disbenefit the most from the introduction of the charging scheme, this is balanced by a greater proportion of non-compliant cars being owned by the lower income population.

Table 38: Summary assessment of distributional analysis

Scenario	Air quality	Affordability for households	Traffic (Accessibility)
CAZ 1	✓	××	-
CASAP	✓✓	×	×

3.8 Final Appraisal

For final stage of the study, the appraisal outcomes can be summarised as follows:

3.8.1 Air Quality Impacts

- The baseline in 2021 does not comply with the annual mean NO_2 limit value with out further interventions.
- The modelling of the preferred option indicates that significant improvements in NO_2 concentrations are achieved on Castle Street ensuring that compliance with the NO_2 limit value is met in 2021. The results indicate that there is a greater than 90% chance that compliance will be achieved based on probability distribution analysis.
- The CAZ option in the modelled 2021 future year is predicted to also comply with the NO_2 limit but is uncertain if such scheme could be implemented before 2021, given no finalised framework or regulations have been made by Welsh Government.
- The non-charging package delivers overall wider air quality benefits, and further reductions of emission pollutants such as PM2.5. **The CAZ scenario leads to an increase in PM2.5 emissions.**
- Air quality impacts accounted for in the Economic Appraisal from the preferred option demonstrate a real reduction in pollution and associated increased health standards, as opposed to the CAZ measure, which has been shown to displace, rather than reduce emissions.
- The CAZ would place direct costs on households, where as the main impact of the CASAP measures is increase journey times.

3.8.2 Summary Appraisal Tables

Individual Summary Appraisal Tables for the preferred option and the CAZ 1 option are presented below and have been further updated following the completion of the Economic Appraisal. Table 42 provides an overall summary of these assessments.

3.8.3 Assessment against Well-being Objectives

The appraisal summary tables have been amended to include appraisal of the preferred option and CAZ1 against the Well –Being Objectives for further comparison.

Table 39 - Preferred Option Summary Appraisal Table

Name of Measure : Preferred Option – Non Charging Measures			
Timescales		**2019-2021**	
Feasibility		**Yes – Timescales for full implementation are extremely challenging**	
Effective:		**Highly Effective– the package of measures achieve compliance on Castle Street**	
Objective		Summary of Key Impacts	Assessment Qualitative
Environment	Air Quality	The modelling results of the final package indicates a reduction of NO_2 concentrations of nearly 10 µg/m^3 on Castle Street which achieves compliance.	Significantly Beneficial +3
	Noise	The implementation of Zero Emission Buses, plus the retrofitting of remaining buses, and the improved highway arrangements, will improve noise levels.	Significantly Beneficial +3
	Landscape	The implementation of the CCN and CCW schemes, will have significant improvements in terms of landscape/ green infrastructure which will be implemented as part of the schemes.	Moderately Beneficial +2
	Historic Env	Whilst the highway improvements works on Castle Street, will cause initial disruption in front of Cardiff Castle it is anticipated that upon completion the works will improve the built environment in the City Centre and the area around Castle Street.	Moderately Beneficial +2
	Biodiversity	The scheme will not negatively impact on biodiversity nor will it impact any protected sites.	Neutral 0
	Water Environment	It is unlikely that the measure will impact the River Taff, River Ely or Rhymney River or the Severn Estuary and thus there will be no negative impact to the water environment. As part of the CCW scheme drainage improvements will be undertaken, and thus it could be argued that improvements to discharge to the River Taff will be improved. There will also be a requirement for sustainable drainage solutions to be included in the schemes.	Slightly Beneficial +1
	Townscapes	No direct impacts are anticipated to listed buildings or other buildings as part of the proposed measures. However the City Centre schemes will have significant public realm and landscape aspects.	Moderately Beneficial +2
	Greenhouse Gas Emissions	Owing to upgrade of buses and taxis there is a reduction in GHG emissions (CO2) however this is offset by the increase in journey times from the City Centre works .	Moderately Adverse -2
Economy	Journey Time Changes	Journeys by public transport, and active travel modes are likely to increase owing the improvements in the highway network, efficiency of movement and prioritisation. Owing to the prioritisation of sustainable and active travel modes, there is likely to be an impact on private and commercial vehicles who may have taken alternative routes or face delays in the city centre which will lead to an increase in journey times.	Moderately Adverse -2
	Capital Costs	High >£2M It is anticipated total costs of the projects as follows: Bus Retrofit £2.25m Taxi Mitigation Schemes £1.86m City Centre Schemes £15m* 20 mph areas £1.2m	High
	Land	No loss of land is anticipated from this measure.	Neutral 0
Social and Cultural	Journey Quality	Implementation of Zero Emission Buses, will provide high quality transportation, and the retrofitting of the remaining Cardiff Bus Fleet, should improve journey quality on the remaining buses. Active travel measures included should improve the journey quality within the city centre and wider areas of the City.	Significantly Beneficial +3
	Physical Activity	The active travel packages and elements to improve active travel within the City Centre Schemes should see a significant uptake and increase in active travel.	Significantly Beneficial +3
	Accidents	Improvements to the City Centre traffic, expansion of 20 mph areas, and segregation of cycling should see an overall reduction in accidents across the City.	Significantly Beneficial +2
	Access	It is not anticipated that the implementation of the package of measures will have an impact on access to services, employment, or healthcare within Cardiff. There could be increased access for some members of society by encouraging walking and cycling.	Moderately Beneficial +2
Value for Money	Value for Money	The NPV for this measures is - -£314m over 10 year assessment period	£-314m

Name of Measure : Preferred Option – Non Charging Measures			
Well-being and Future Generations - 7 Ways of Working	Prosperous	The City Centre schemes will provide high quality sustainable transport connections to key regional and national transport hubs, major employment sites and leisure destinations. The schemes will also deliver a reduction in traffic that will result in a significant improvement in Air Quality.	Moderately Beneficial +2
	Resilient	This option requires a high amount of resources for implementation, both financial costs and physical resources. However, it is likely to score as neutral for this well-being goal.	Neutral 0
	Healthier	The preferred option delivers significant air quality improvements not only in the area of non-compliance but city wide. Overall reductions of PM2.5 have also been modelled. This will have positive impacts on the health of the citizens and visitors to Cardiff.	Significantly Beneficial +3
	More Equal	The measures do not target any one group in society and do not cause any one to be disadvantage. The increase in active travel and support for public transport schemes should provide benefits to more disadvantaged communities.	Slightly Beneficial +1
	Cohesive Communities	The measures will provide, modern, active and effective transport solutions in the heart of the capital city of Wales. These areas are key to connecting the city, the region and the nation with major development works in Central Square, key transport hubs (Central Station and Transport Interchange) and some of the city centre's most popular leisure destinations (National Stadium and Retail). The measures also ensure that compliance with EU limit value can be achieved.	Moderately Beneficial +2
	Vibrant Culture and Thriving Welsh Language	This measures are not likely to influence areas that make a vibrant culture and ensure a thriving welsh language and scores as neutral for this goal.	Neutral 0
	Globally Responsible	Poor air quality is recognised globally as a major health and environmental issue that needs urgent action. The preferred option has demonstrated significant improvements in air quality can be achieved. Further the measures provide significant reductions in CO_2 which will significantly contribute to GHG reduction and movement towards zero carbon targets.	Moderately Beneficial +2

Table 40 - CAZ Scenario 1 Summary Appraisal Table

Name of Measure : CAZ Scenario 1			
Timescales		**2019-2021**	
Feasibility		**No – unlikely that the CAZ including all operational issues can be fully implemented by 2021.**	
Effectiveness		Yes – the assessment of the scheme indicates NO_2 concentrations achieve compliance.	
Objective		Summary of Key Impacts	Assessment Qualitative
Environment	Air Quality	The modelling results of the CAZ 1, indicate a reduction of NO_2 concentrations of 8.6 µg/m^3 on Castle Street. However areas outside the CAZ see an increase of NO_2 concentrations	Moderately beneficial +2
	Noise	This measure may see the reduction of vehicles on the road, and thus lead to a decrease in road traffic noise.	Slightly Beneficial +1
	Landscape	The introduction of this measure will have no impact on landscapes.	Neutral 0
	Historic Env	The scheme will not have any direct impact on Cardiff's historic landscapes. However any CAZ will require new infrastructure which would be required on Castle Street and surrounding zone.	Slightly Adverse -1
	Biodiversity	The scheme will not negatively impact on biodiversity nor will it impact any protected sites.	Neutral 0
	Water Environment	It is unlikely that the measure will impact the River Taff, River Ely or Rhymney River or the Severn Estuary and thus there will be no negative impact to the water environment.	Neutral 0
	Townscapes	The installation of the ANPR cameras will be required to operate the scheme and thus could have a negative impact on the townscape of the City Centre	Slightly Adverse -1
	Greenhouse Gas Emissions	Given that Euro 4 petrol cars are compliant there could be an increase in older petrol cars (Euro 4), which have higher CO2 emissions compared to diesel vehicles. However could also see an increase of Euro 6 diesels or ULEVs, which would negate the impact on GHG emissions.	Slightly Adverse -1
Economy	Journey Time Changes	It is possible that journeys times will increase for non-compliant vehicles that avoid the CAZ in order not pay the charge. However compliant vehicles may see an increase in journey times as road space is freed up.	Neutral 0
	Capital Costs	Estimated costs for the implementation of the CAZ are in the region of £3.2m. The implementation of the ANPR network and the development of the required operations team will require significant upfront costs. In addition consideration of vehicles upgrade costs for wider society need to be considered.	<High
	Land	No loss of land is anticipated from this measure.	Neutral 0
Social and Cultural	Journey Quality	The removal of non-compliant vehicles could improve the vehicle journeys within the CAZ. However those driving non-compliant vehicles, may have decreased journey quality owing to having to avoid the CAZ in order to not pay the charge.	Slightly Beneficial +1
	Physical Activity	Users of non-compliant vehicles making short trips to the City Centre may switch travel mode and switch to active travel modes. Alternatively non-compliant vehicles will park further from the CAZ area, and thus walk further into City Centre.	Slightly Beneficial +1
	Accidents	It is not anticipated that the introduction of CAZ will have a direct impact on accident rates. It could be argued that if there are fewer vehicles owing to reduction in non-compliant vehicles in the CAZ area, then there could be a positive impact on potential accidents	Slightly Beneficial +1
	Access	Potential this could impact on the ability for citizens to access services, employment, or healthcare within Cardiff if their vehicles are non-compliant and the have to pay the user charge. However as the CAZ is a small zone where public transport access is good, then those persons who are not able to upgrade vehicles, could still access the area by alternative means.	Moderately Adverse -2
Value for Money	Value for Money	A negative NPV of £-52m has been calculated in the CBA	£-52m
Well-being and Future Generations - 7 Ways of Working	Prosperous	This measure could negatively impact local economy and provision of local services by discouraging trips into and through the zone.	Slightly Negative -1
	Resilient	This measure requires notable resource for implementation. However, the measure can positively impact on the ecosystem by removing poor quality vehicles that negatively impact on local air quality readings. However initial assessment indicates that individuals swap older diesels for Euro 4 petrol vehicles which results in increase in CO2 emissions.	Neutral 0
	Healthier	The CAZ1 option delivers air quality improvements in the area of non-compliance. Howevever, the increases in NO_2 concentrations modelled on the peripheral of the CAZ and wider across the City as per the DIA, offsets the benefits gained on Castle Street.	Slightly Beneficial +1
	More Equal	The CAZ charge is based on vehicle emission standards and does not take account of personal income and ability to pay. The DIA indicates that whilst the least deprived	Moderately Negative -2

Name of Measure : CAZ Scenario 1			
		quintiles will be most impacted due to a greater number of trips into the CAZ. the least deprived groups will also be severely impacted due to this group having a higher number of non compliant vehicles. These are likely to be impacted more than those that are more financially secure as they are less likely to afford an upgrade to compliant vehicles.	
	Cohesive Communities	This measure will may impact on deprived groups ability to access key services/ facilities in the City Centre and thus cause further dis benefit to them and create further isolation.	Moderately Negative -2
	Vibrant Culture and Thriving Welsh Language	This measures are not likely to influence areas that make a vibrant culture and ensure a thriving welsh language and scores as neutral for this goal.	Neutral 0
	Globally Responsible	Poor air quality is recognised globally as a major health and environmental issue that needs urgent action. The assessment shows that the CAZ 1 option will leads to an increase in PM2.5 emissions for the baseline 2021 year.	Slightly Beneficial +1

Table 41 - Revised Assessment of Options against Primary and Secondary Objectives

*Considered overly ambitious given full consultation, planning, procurement, orders, ministerial approval and operational practicalities faced in the time period.

Measure Description	Primary Objective Achieved (If Pass- expected year of compliance)	Secondary Objectives (Scores 1. Low, 2. Medium, 3. High 4. V. High)							Scores	Judgement
		Will the measure deliver an overall reduction in NO_2 emissions to air.	Will the measure result in additional benefits or other environmental impacts (i.e., GHG Reductions	Will the measure contribute to well-being		Does the option fit or compliment other local policies.	Value for Money - Do the likely benefits of this option exceed the costs	Constraints on Implementation of Measure		
				Positive impact on wider public health.	Mitigate financial impact on low income households and reduce inequalities					
Revised Non Charging Measures Package	Pass (2021)	4	2	4	4	3	1	2	20	Preferred Option
CAZ 1 – Private Cars	Fail*	3	3	2	1	1	1	2	13	Unlikely Option

Table 42 - Summary of WelTAG Well-being Aspects Appraisals

	Key Criteria			Environment								Economic			Social and Cultural				VfM	Well-being and Future Generations - 7 Ways of Working							Outcome
Measure	Timescales	Feasibility	Effectiveness	Air Quality	Noise	Landscape	Historic Environment	Biodiversity	Water Environment	Townscape	Greenhouses Gas emissions	Journey Time Changes	Capital Costs	Land	Journey Quality	Physical Activity	Accidents	Access		Prosperous	Resilient	Healthier	More Equal	Cohesive Communities	Vibrant Culture and Thriving Welsh Language	Globally Responsible	
Non Charging Measures	Y	Y	Y	+3	+3	+2	+2	0	+1	+2	-2	-2	High >£2 M	0	+3	+3	+2	+2	£-314m	+2	0	+3	+1	+2	0	+2	**Preferred Measure**
CAZ 1 Scenario	Y	N	Y	+2	+1	0	-1	0	0	-1	-1	0	High >£2 M	0	+1	+1	+1	-2	£-52m	-1	0	+1	-2	-2	0	+1	Unlikely Measure

Key

+3 = Significantly Beneficial +2 = Moderate Beneficial +1 = Slight Beneficial 0 = Neutral -1 = Slight Adverse -2 = Moderate Adverse -3 = Significantly Adverse

3.9 Conclusions on the Economic Case

The results of the assessments indicate that both the Preferred Option package of non-charging measures and the CAZ scenarios provide compliance on Castle Street, which under the baseline do nothing scenario demonstrated continuous non-compliance issues for the NO_2 Limit Value beyond 2021.

The results indicate that the preferred option delivers the most significant improvements in terms of NO_2 concentrations on Castle Street with a projected concentration of 31.9 μg/m^3 modelled. In terms of the air quality benefits the preferred option of the non-charging measures significantly outweighs the air quality benefits of the CAZ option. In addition the analysis indicates that the preferred option has a positive impact on reducing levels of $PM_{2.5}$ as they are modelled to decrease by 0.34 tonnes in the initial year compared to the do nothing scenario. The CAZ scenario actually sees an increase in $PM_{2.5}$ emissions compared to the baseline scenario.

The CBA undertaken shows that both options have a negative NPV, meaning that the cost of the options due outweigh the realised benefits. In terms of the preferred option, the most significant proportion of the calculated disbenefit comes from the additional travel time because of the City Centre Schemes. However, it has to be stressed that this is not a direct 'pocket' cost to individuals, but is a monetised value of the extra time taken to travel. To put this into perspective the distributional analysis indicates that for 75% of the additional journey times, the increase is only 0-5 minutes, and only 1% of the journeys increase by more than 10 minutes. The most affected part of the City in terms of increased journey times appears to be for journeys from the North West.

The analysis undertaken to calculate this disbenefit is a very conservative estimation and has likely over calculated the true disbenefit. This is owing to the limitations of the modelling, and it is important to remember however, that the city centre schemes have been modelled with a fixed demand in the transport model. Therefore, the modelling of travel times only accounts for that traffic diversion rather than any switching of mode or trip supersession. In reality there will be a significant percentage of trips that may switch to other means of transport or be cancelled which would reduce the time impact, as well as have a number of knock on effects as reduced traffic levels. **This is an important limitation of the modelling and does not allow one of the key benefits of the City Centre schemes to be fully assessed which is to encourage modal shift to active and public transport alternatives.**

The Net Present Value does not paint a full picture of the impacts of either scheme. There are likely to be dynamic responses to changes in congestion and new road measures introduced that cannot be accounted for. Moreover, it is important to recognise the inherent benefit that the measures reduce air pollution in line with targets. **While the reduction in pollution is monetised to determine a benefit, it is difficult to truly quantify the health benefit associated with reducing air pollution to 'acceptable' levels and beyond**. It is also important to note that while both measures reduce the level of pollution, the analysis of the non charging measures shows that a real reduction in emission occur, with corollary health benefits.

Further the following points also need consideration:

- The analysis does not take into account additional mitigation measures being considered by the Transport Policy Team, specifically the implementation four Improvement Corridor Projects that will look to mitigate against the residual impacts and encourage further mode shift to sustainable modes. These are

  - SMART Corridor North (A470);
  - SMART Corridor West (TBC – Subject to feasibility study);
  - SMART Corridor East; and
  - Riverside and Grangetown Improvement Corridor

- The analysis does not take into account the major projects and interventions committed to or identified by the forthcoming new Transport Vision. These could potentially offset the increased journey times arising from the proposed measures.

- The negative economic impact of the preferred option equates to roughly £30m a year over the 10 years assessment period. This is for an economy worth around £10bn per year therefore accounting for only 0.3%. Again, this is not an actual cost to business or individuals.

- The analysis also does not consider wider cost to the Council/ public purse of:

  - Any possible fines associated with any continued breach of the EU limit value; and
  - The impact on tourism and inward investment of being a city with a reputation for having poor quality air / poor transport

- Taken together, any financial value attributed to the above should more than offset the negative economic impact attributed to the productivity loss.

The assessments have also assessed how the measures could affect various demographics as part of a Distributional Impact Assessment that has been undertaken. The results indicate that the most deprived part of the population as well as the population with the highest proportion of children would have the most air quality improvements with the preferred option of non-charging measures.

In addition, a charging scheme will lead to much greater costs to households due to the direct and indirect impact of the charges. The assessments show that whilst a higher income of population would disbenefit the most from the introduction of the charging scheme, this is balanced by a greater proportion of non-compliant cars that are owned by the lower income population that would have to pay the charge as they would unlikely afford to upgrade to compliant vehicles. The high income population would likely be more able to upgrade or afford to pay the charge.

Welsh Government policy[49] states that unless the Council can identify alternative measures to achieve compliance as quickly as a charging clean air zone then Welsh Government may direct the Council to introduce a charging clean air zone. The assessments undertaken to date demonstrates that non charging measures provide compliance in the same period if not sooner than a CAZ, as Welsh Government have assessed that a CAZ could take up to 3 years to implement from the start of a feasibility study.

[49] https://gov.wales/sites/default/files/publications/2019-04/tackling-roadside-nitrogen-dioxide-concentrations-in-wales.pdf

Further additional guidance from the UK government[50] , through their Joint Air Quality Unit (JAQU), indicates that a charging CAZ should only be implemented if non charging alternatives are shown not to achieve compliance in the shortest possible time.

An important point in the CBA is the positive health benefits of the CASAP option in terms of improved air quality (£4.8 million benefit) and active travel benefits (£15 million benefit). In comparison the CAZ 1 option indicates an overall negative health benefit as air quality is worsening in some areas, which is counter to the overall objective of reducing air pollution to improve public health, and it does not generate any active travel benefits.

Overall the evidence suggests that the CASAP scheme should be taken forward as the preferred option because:

- It achieves compliance by the greatest margin and is robust under the sensitivity tests carried out;
- It generates the greatest health benefits from both air quality improvements and active travel benefits, compared to the CAZ option which in fact generates an overall negative health benefit;
- The benefits generated by the CASP option fall most to low income and disadvantaged groups to supports wider social goals; and
- Although the NPV is worse for the CASAP option the dominate factor driving the negative NPV is associated with some uncertainty. Also, the legal ruling in relation to compliance sets out that costs are not a material consideration in terms of achieving compliance as soon as possible.

Furthermore the nature of the measures within the preferred option means that the initial delivery of some of the measures can occur during the course of achieving compliance something that would not be achieved by implementing a charging clean air zone. As part of the requirements of the legal tests in the ruling of the ClientEarth 2[51] (CE2) case, the court has stated that in order to comply with Article 23 of the EU Directive; local authority plans must ensure that they *'Choose a route to compliance which **reduces human exposure as quickly as possible'***. In essence this means that a plan which aims to achieve compliance by a certain date throughout the entirety of the zone would not meet the legal test, if there were short term additional or alternative measures identified that could lead to compliance and reduction in human exposure in a shorter time period.

Based on the emphasis to start implementing measures in the short term, in order to comply with the legal test the Council should not delay in implementing the measures included in the preferred option, and hence the package of non charging measures remains preferred option for Cardiff Council.

[50] JAQU Guidance – Evidence Based Approach to Setting Clean Air Zone Charges

[51] **1 ClientEarth (No. 2).** https://www.judiciary.gov.uk/wp-content/uploads/2016/11/clientearth-v-ssenviron-food-rural-affairs-judgment-021116.pdf

Section 4 Commercial Case

JAQU's Inception package guidance requires the Commercial case for the FBC to include the following:

- The detail of contracting, procurement and payment mechanisms (assuming for CAZs) should be outlined.
- Wider financial implications of the scheme should be detailed as well as the capital and revenue implications.

This commercial case outlines how each of these measures within the package will be delivered., in terms of any procurement, and contract awarding.

4.1 Introduction

This chapter presents the Commercial Case for the proposals to be funded through the Clean Air Fund and clarify the use of other available funding streams to implement the package of preferred measures. It explains the proposed procurement strategy in the context of the sourcing processes that will be used to engage with the market. It then outlines the proposed contracting strategy for the ongoing management of the awarded contracts and associated risks as implementation progresses.

Certain measures included as part of the preferred package will be financially supported by existing funding streams and the offered Clean Air Fund. Measures encapsulated by various funding mechanisms is specific to the City Centre Transport improvement schemes and development of 20mph and active travel zones. As referenced in the Financial Case, Tables 44-46 disaggregates the contributions made available via the LTF scheme.

Given the variety of works proposed, there are several procurement options available. Much of the work can be procured through existing frameworks and contractual arrangements, hence facilitating the early delivery of each of the measures especially where critical.

It is viewed that the implementation of the preferred package of measures and delivery of the critical success factor to compliance in the shortest possible time, is considered to more deliverable from a procurement perspective. Via existing frameworks and professional partnerships procurement for the preferred package of measures is deemed more straight forward and manageable, and hence it is quicker to implement the main elements of the proposals and to generate the benefits and deliver the critical success factor, in comparison to a charging CAZ. Therefore, this is reflected in the ability to deliver the preferred scheme in the shortest possible time.

4.2 Cardiff Council's Capability to Deliver

The feasibility study and development of a business case for delivering compliance has been resourced by Cardiff Council's Clean Air Project Team, with support from the Transport Planning Policy & Strategy Group, and appointed external Transport and Air Quality consultants.

Post submission of the Full Business Case, in order to oversee the day-to-day management of implementing the preferred option it is essential that additional resource will be allocated to Cardiff Council's Clean Air Project Team.

4.3 Output Based Specification

The Commercial Case is based on strategic outcomes and outputs, against which alternative procurement options are assessed. The outcomes, including those relevant secondary critical success factors for the project which the procurement strategy must deliver, are to:

- achieve a level of certainty that the proposed package of measures scheme will be delivered within any funding constraints;
- minimise preparation costs by ensuring best value and appropriate quality in relation to scheme design elements;
- identify and utilise internal experience, as well as contractor experience to develop of a coherent implementation programme for the proposed package of measures; and
- seek internal and contractor input to manage risk, including mitigation measures, to capitalise at an early stage on opportunities to reduce risk.

4.4 Procurement Strategy Sourcing Process

Governance of the sourcing process will follow the Council's procurement procedures and policies rules to ensure in all cases they meet the strategic objectives of:

- delivering best whole life value for money;
- conforming to the Council's contract procedure rules, as well as National or European procurement procedures
- complying with all relevant legislation and existing frameworks;
- conforming to the Council's contract procedure rules as well as national;
- being open and transparent and providing all necessary safeguards against fraud and corruption;
  being properly documented providing clear audit trails;
- ensuring active and widespread involvement with the Council, making it as easy as possible to engage; and
- make sure that the Council's procurement strategy supports the organisation to achieve its sustainability, environmental and diversity policies.

In terms of the City Centre Improvement Scheme, Transport Services in Cardiff Council will be responsible for the management of the procurement process. All procurement activities will be delivered in adherence with the Council's corporate procedures and standards. Procurement process will commence once the approved funding has been agreed. The Clean Air Project Team will liaise with the Transport Services, on approvals to develop, progress and award contracts, in line with the Council's contract procedure rules.

4.5 Objectives and measurement

Primary and secondary objectives for procurement have been identified for the preferred scheme and are detailed below. The proposed procurement options must deliver the following primary objectives. It must:

- deliver the preferred scheme within the available funding;
- ensure that value for money is delivered;
- ensure that appropriate quality is delivered;
- reduce risks to an acceptable level;
- comply with current legislation; and
- comply with any grant conditions.

A number of secondary objectives have been identified, which would be beneficial, if they could be delivered through the chosen procurement option. The secondary objectives include to:

- engage contractors early in the project planning
- provide contractor input to the design, risk and programme
- work with a proven considerate contractor (desirable)
- maximise the opportunities for local employment (desirable).

There are two key criteria against which the suitability of the sourcing approach is judged. These are;

- Price certainty - cost certainty and limiting risk is a key objective for the preferred scheme.
- Timing - in order to ensure funding is obtained from the Clean Air Fund, a start on delivery must occur in 2019/ 20 financial year and deliver a completed project in the shortest possible time and with no delay to the achievement of compliance with NO_2 concentration limits.

Table 43 shows a summary of the measures required to implement the preferred option and the associated procurement routes where required. Further detail on the commercial case for each measure is also presented in this section.

Table 43 - Preferred Option Measures and Procurement Routes

Measure	Description	Procurement Route	Contract Length	Contract Manager	Contract Type
Electric Bus Scheme	Cardiff Council has a professional partnership with Cardiff Bus operator. Collaboratively, in 2018 a successful bid application was submitted for 36 full electric bus vehicles.	Funding has been secured from Department of Transport (DfT), from their ULEB Grant.	3 years.	Cardiff Council's Clean Air Project Team.	Grant agreement.
Bus Retro Fit Scheme	The retro fit programme would see applicable bus vehicles (operated in Cardiff) fitted with the necessary upgrades to produce an emissions output equivalent to a Euro VI bus vehicle. To date **150 bus vehicles** applicable to the proposal have been identified.	None. Cardiff Council's Clean Air Project Team to replicate and manage the DfT's CBTF scheme, acquiring tender applications adhering to the conditions set out by the devised scheme. Bus operators will be responsible for the procurement of technology providers.	2 years max.	Cardiff Council's Clean Air Project Team.	New Contract agreement.
City Centre and Active Travel Schemes	Increased efficient movement of public transport (buses) and increase active travel capacity in the City Centre. Such schemes will also look to reduce highways capacity for private vehicles. Three schemes are proposed to complete the City Centre 'Loop' and are intrinsically linked to the Integrated Transportation Hub in Central Square; City Centre West, City Centre North & Eastside Phase 1.	Via a tender process, utilising the South East Wales Highway (SEWH) Framework, Cardiff Council's Transport, Strategy and Policy Team will award the scheme's construction works.	3 years.	Cardiff Council's Transport Planning Policy and Strategy Team/ Cardiff Council's Clean Air Project Team.	New Contract agreement.
20mph Zones	Expansion of 20mph limits, primarily targeting the ward of Grangetown, Cardiff.	Via a tender process, utilising the South East Wales Highway (SEWH) Framework, Cardiff Council's Major Project Development Team will award the scheme's construction works.		Cardiff Council's Transport Strategy and Policy Team/ Cardiff Council's Clean Air Project Team.	New Contract Agreement.

Measure	Description	Procurement Route	Contract Length	Contract Manager	Contract Type
Taxi Licensing Condition Change	Revision to Taxi Licensing Policy to include emissions standards. As proposed; Cardiff new licences and licence renewals, vehicles must conform to being Euro 6.	None.	None.	None.	None.
Taxi Licencing Incentive Scheme	To increase the uptake of 0EV & ULEV licensed vehicles in Cardiff. The incentive will be made available to the first successful 600 applications (equivalent to 30% of licensed fleet). To note; ULEVs are defined by HM Treasury as "a vehicle that emits less than 75g of carbon dioxide emissions per kilometre travelled and can drive a minimum of 10 miles in zero emission range".	Cardiff Council's Licensing Team and Clean Air Project Team will manage and facilitate a subsidiary grant scheme (Cardiff Council 0EV & ULEV Taxi Incentive Scheme) for Cardiff licensed taxi drivers and owners/ operators. Direct grant award from Cardiff Council's Licensing Team to successful applicant.	3 years from receipt of successful application.	Cardiff Council's Licensing Team and Clean Air Project Team.	Grant agreement.

4.6 Procurement Routes

4.6.1 Electric Bus Scheme

Measure Description

In 2018, in collaboration with Cardiff Bus operator, a successful bid application was secured from Department of Transport (DfT), via the Ultra-Low Emission Bus (ULEB Grant). The successful bid application supported a certain percentage contribution to facilitating the uptake of 36 full electric bus vehicles.

This successful bid for 36 vehicles and supporting infrastructure provides a platform to begin the transition to a low carbon fleet. The uptake of 36 ULEV buses will result in 15% of the Cardiff Bus operator fleet being certified as Ultra Low Emission. As a secondary benefit, the ULEB vehicles enables a fleet cascade programme to replace 36 Euro III vehicles, many of which operate within the boundary of the AQMAs.

Key Milestones

- Order and Implementation of power infrastructure - In discussions with suppliers Cardiff Bus have indicated this could take up to 8 months to complete.
- Order units (buses) by March 2020. Based on discussions with Cardiff Bus there is an approximate lead-time of 8 months for bus 36 units to be delivered and implemented by the end of the financial year 2020/ 21.

Total Cost

No associated cost. Cabinet have been asked to consider providing this as a commercial loan from the Council, in addition to a sum of £2 million previously requested in order to support the Company's acquisition of vehicles. Owing to state aid issues no further grant funding is possible or being sought for this measure with the costs to be borne by the company as part of its long term fleet replacement.

The cost per electric bus is **£362,666 (ex VAT).**

The cost for charging infrastructure (not including supply/ connection costs) is **£444,960 (ex VAT).**

Procurement Route

No associated procurement. Cardiff Bus has been approved as the lead organisation of the grant fund, and thus takes on full responsibility of acquiring approved contractors and suppliers to facilitate the bid application; ADL/BYD and SSE/ Powersytems.

4.6.2 Bus Retro Fit Scheme

Measure Description

Owing to the previously offered Department for Transport's (DfT) Clean Bus Technology Fund (CBTF), subject to legal advice surrounding State Aid, Cardiff Council's Clean Air Project Team proposes to function as a regulatory entity to manage, regulate and fund such a retro fit scheme with Cardiff based bus operators.

The retro fit programme would see applicable bus vehicles fitted with the necessary upgrades to produce an emissions output equivalent to a Euro VI vehicle. Replicating the conditional criteria outlined in the DfT's CBTF, to successfully qualify for the provided funding it is a main requirement that those vehicles identified for the accredited technology upgrades are expected to be operational for a further 150,000 miles or operational for minimum of 5 years after the relevant upgrades.

Following the discussions with senior representatives from the various operators, Cardiff Council received a good level of positive interest and commitment. To date **150 bus vehicles** applicable to proposal have been identified. These vehicles operate solely in Cardiff or Cardiff based routes, therefore they will positively attribute to improving roadside emissions in Cardiff.

Key Milestones

Following legal advice, Cardiff Council's Clean Air Project Team would look to administer the scheme by end of 2019 with an aspiration to go 'live' with the scheme at the start of 2020. It is envisaged that appointed operators will start the retro-fit programme start of the 2020/21 financial year. Upon application approval the retro fit programme will be funded for one year.

Total Cost

Based on the envisaged uptake of 150 buses the total funding requirement for this scheme would be approximately **£2,250,000 (ex VAT).** It is understood, on average, the cost of upgrading 1 vehicle with the appropriate accredited technology and telematics amounts to approximately £15,000 (ex VAT).

Procurement Route

No associated procurement. In terms of procuring a supplier for the accredited technology this will be the responsibility of the bus operator, therefore no direct procurement will be untaken by the Council. It must be noted, in line with the Clean Vehicle Retrofit Accreditation Scheme (CVRAS), using the CVRAS register, various products and suppliers can be located to support and facilitate individual operator needs.

Applications will be scored accordingly with respect to four key aspect areas; Strategic Alignment, Delivery of Air Quality Benefits, Deliverability & Value for Money.

Table 44 - Bus Retrofit Scheme Contractual Detail

Duration of Contract	**Max 2 years.**
Roles/ Responsibilities	Cardiff Clean Air Project Team- administer contract, perform initial sifting process for received applications, award funding to operators and review progress reports submitted by operators. Operator - Provision of required evidence to demonstrate compliance with the proposed scheme.
Payment Mechanism	Grant scheme will reimburse Capital Costs incurred on a quarterly basis, following receipt of Operator's quarterly progress reports.
Allocation of Risk	Risk is allocated to the grant's recipient operator to appoint an appropriate accredited technology supplier and to ensure vehicle remains compliant with the grant's obligations. Cardiff Clean Air Project Team will not reimburse capital costs if quarterly progress reports fail to demonstrate compliance with the grant's conditional criteria.

Scheme Obligations

Applicants will be expected to demonstrate, in detail, how their proposal will perform in terms of the four key aspect areas.

As will be outlined in the scheme's application conditional criteria; applicants are required to appoint the use of accredited technology which is compliant with the **Clean Vehicle Retrofit Accreditation Scheme (CVRAS).**

The buses to be retrofitted can be any pre-Euro VI bus that is expected to be operational on the specified routes for at least five years or for 150,000 miles after the retrofit. Buses will note be authorised to be moved to other localities outside the boundary of Cardiff.

In accordance with the successful applications, recipients will need to submit interim progress reports each 3 months after project inception, with a draft final report reflecting on the impact of the activities initiated by the grant funding.

The Grant is to reimburse Capital Costs incurred and may be spent on the Accredited Technology and cost of fitting it to the buses, and the cost of and fitting of monitoring equipment. The Grant **may not** be spent on:

- Staff costs for managing the project;
- contributions in kind;
- payments for activities of a political or exclusively religious nature;
- depreciation, amortisation or impairment of fixed assets owned by the authority;
- input VAT reclaimable by the authority from HM Revenue & Customs;
- interest payments or service charge payments for finance leases;
- gifts, other than promotional items with a value of no more than £10 in a year to any one person;
- entertaining (which means anything that would be a taxable benefit to the person being entertained, according to current UK tax regulations); and
- statutory fines, criminal fines or penalties.

State Aid

Applicants must confirm that they have received legal advice on EU State Aid rules, and provide a summary of that advice to confirm how the project proposal would fit within the relevant rules. A Recipient must ensure that all agreements it enters into in connection with the Project comply with EU State aid rules and enable the Local Authority to recover any grant which is deemed to be unlawful State Aid. We reserve the right to refuse an application where there are significant concerns about State Aid that are not addressed in the advice provided.

Applicants must meet the project management and other operational costs incurred by the technology.

4.6.3 Centre Schemes and Active Travel Measures

Measure Description

The main purpose of these schemes is to allow for better and more efficient movement of public transport (buses) and increase active travel capacity in the City Centre. Such schemes will also look to reduce highways capacity for private vehicles which will is intended to be a catalyst for increase modal shift to public and active travel.

Three schemes proposed are intrinsically linked to the Integrated Transportation Hub in Central Square.

-City Centre North;
-City Centre West; and
-Eastside

Key Milestones

- Public Consultation on Schemes Summer 2019
- Tender on Schemes Q2 19/20
- Initiate procurement Quarter 3 financial year 2019/20.
- Construction phase in accordance with Air Quality Improvements proposed for completion for the end of 2021.

Total Cost £15.2m

Procurement Route

Through the use of correct procurement and tendering process the project will benefit from the highest level of quality and experience from suppliers. Pre delivery procurement will be sourced under Nation Procurement Service (NCP) Construction Consultancy Framework.

The construction of the project will be sourced under the South East Wales Highway Framework (SEWH). Payment will follow current Local Authority contractor payment terms, this will involve a valuation and payment at four week intervals.

Key to the success of the frameworks is the options for a flexible approach for clients, whilst support being available at all times; including online guidance documents; legal advice; and the opportunity to take part in various working groups

In order to provide value for money the delivery of the project will include a competitive tendering process for the appointment of a contractor. Community Benefits will be included within the tender evaluation.

Table 45 - City Centre Transport Improvement Schemes Contractual Detail

Duration of Contract	**The anticipated contract length for each scheme varies with each phase, typical lengths range from 9-21months.**
Roles/ Responsibilities	The procurement process with be managed by the Council's Design, Contracts and Delivery Section/ as well as Cardiff Council's Transport Planning Policy and Strategy Team. This process will commence once total funding has been confirmed. Contract type used will be the Engineering and Construction Contract (ECC), which is part of the New Engineering Contract (NEC3) family of contract documents.
Payment Mechanism	There are five payment options within the ECC: A. Priced contract with activity schedule B. Priced contract with bill of quantities C. Target contract with activity schedule D. Cost reimbursable contract E. Management contract Each individual project area will be assessed independently before the procurement stage to identify which contract arrangement works best for each scheme.
Allocation of Risk	During the construction phase of the project risks and associated cost items will be identified, assessed and managed depending on which project contributor is

	best placed to manage them. Project Management tools such as Issue and Risk Registers have been used during the research and design phases, and they will continue to be used during construction. All risks are assessed using Cardiff Council's Risk Matrix and Risk Assessment Criteria. Due diligence during framework procurement ensured necessary checks around commercial viability and track record were undertaken. Payment mechanism ensures invoice upon satisfactory delivery of requirements.

4.6.4 Active Travel- Expansion of 20mph Zones

Measure Description

The Council proposes to expand its commitment to 20mph zones and include 3 schemes in the Clean Air bid. These schemes are for the physical measures required within the Grangetown 20mph limit area to encourage greater motorist compliance with the new speed limit and improve the pedestrian and cyclist crossing facilities at key locations within the ward.

The 3 schemes applicable to Grangetown are as follows;

- Avondale Road traffic calming construction;
- Penarth Road Zebra Crossing construction; and
- St Patricks School Safety Zone construction

Key Milestones

Avondale Road;

- Tender & Procurement- End June 2019
- Construction completion- End October 2019

Penarth Road;

- Tender & Procurement- End December 2019
- Construction completion- End February 2020

St Patricks;

- Tender & Procurement- End December 2019
- Construction completion- End February 2020

Total Cost

£1.28 million

Procurement Route

Utilising the South East Wales Highway (SEWH) Framework, Cardiff Council's Major Project Development Team will award the scheme's construction works.

Table 46 - Active Travel/ 20 mph Expansion Contractual Detail

Duration of Contract	**Until works complete- envisaged end of February 2020.**
Roles/ Responsibilities	Cardiff Council's Major Project Development will be contract managing. Successful tender applicant will oversee schemes implementation.
Payment Mechanism	Payment made following successful and timely completion of schemes.
Allocation of Risk	Payment mechanism allocates delivery risk to allocated provider. Failure to deliver key outcomes can prevent receipt of payments. Payment mechanism ensures invoice upon satisfactory delivery of requirements.

4.6.5 Taxi Licensing Condition Change

Measure Description

Cardiff Council is proposing to improve the emission standards of the City's licensed vehicles. Subject to consultation response and Public Protection Committee (PPC) approval, Cardiff Council wish to implement a taxi licensing policy change to improve emission standards for licensed taxi vehicles in Cardiff.

The policy change will require all new grants and renewals for licensed vehicles to have a maximum age limit of 5 years. In essence this will require all **new** grants/ renewals to be Euro 6 emission standards.

Key Milestones

As outlined, subject to approval, the condition will look to be adopted early 2020.

Total Cost

No associated cost.

Procurement Route

No associated procurement. This will be delivered as business as usual by the licensing team in Cardiff.

Contractual Detail

None.

4.6.6 0EV & ULEV Taxi Licensing Incentive

Measure Description

Due to the Council's proposed new age and emissions criteria for licensing new hackney carriages and private hire vehicles, this places a financial burden on drivers and operators licensed within Cardiff to change their vehicles by the implementation date of this policy which will likely be later in 2019 or 2020. This burden is not faced by taxis licensed outside of Cardiff as they are free to compete for trade alongside Cardiff licensed taxis. **This could place Cardiff taxis at a financial and competitive disadvantage.**

In short, the Cardiff taxi trade tends to operate older fleets (the average age of the Cardiff taxis; Hackney Carriage 8.7 years & Private Hire 5.1 years) primarily within the areas of the city where air quality is found to be worst. As such the planned change to taxi licensing restrictions in Cardiff is expected to place some operators under financial pressure.

In order to redress the balance, the Council proposes to introduce a licensing incentive for the first 620 vehicles **~30% of the licensed fleet,** who licence a new 0EV or ULEV taxi with the authority.

The Council is adopting the term “Ultra Low Emission Vehicle” defined by HM Treasury as “a vehicle that emits less than 75g of carbon dioxide emissions per kilometre travelled and can drive a minimum of 10 miles in zero emission range”. This includes all battery electric vehicles and some but not all hybrid vehicles. The London Electric Vehicle (LEVC) TX5 meets this definition, as does the Dynamo Nissan ENV200 hackney carriage conversion.

The incentive will offer operators/ drivers a redemption on their **licensing and operational** fees covering a percentage of the costs for a 3 year period.

In summary, with the applicable funding from the Clean Air Fund, Cardiff Council will offset the loss of licensing fees received from the drivers over a three year period, as well as provide a yearly payment to operators/ drivers who uptake and licence a 0EV or ULEV.

Total Cost

The licensing & operational costs for a new 0EV or ULEV vehicle over a 3 year period has been based upon market rationale and most up to date licence fees. Cardiff Council believes **£3,000** is an attractive offer to drivers/ operators without being excessive, covering approximately 20% of the combined licensing and operational costs over 3 years. Items considered are as follows:

- Insurance: Average £2,500pa
- Licence: HCV (£160pa)/ PHV (£103pa)
- Vehicle maintenance: £500pa(max)
- Vehicle electricity costs (public and home charging): £750pa
- Home charge point (incl. installation fees and government grant): £300 one-off payment.

Procurement Route

No associated procurement. The scheme will be administered by the Council’s established taxi licencing team who are fully supportive of the proposals with additional support from the Clean Air Cardiff Project Team. The Council’s Licensing Team will manage the proposal in house, therefore no procurement or commissioning activities are required to support this measure.

Table 47 - Taxi Mitigation Contractual Detail

Duration of Contract	**3 years following acceptance and successful change of vehicle.**
Roles/ Responsibilities	Cardiff Clean Air Project Team/ Cardiff Licensing Team- administer contract and perform initial and annual quality checks as required by the grant’s obligations. Operator/ Driver- Provision of required evidence to demonstrate compliance with the proposed scheme.
Payment Mechanism	Yearly payments of £1,000 made directly to operator/ driver following yearly quality checks.
Allocation of Risk	Risk is allocated to the grant’s recipient (operator/ driver) to ensure vehicle remains compliant with the grant’s obligations. Cardiff Clean Air Project Team can reclaim grants for breach of contract.

Grant Obligations

The Council proposes the following eligibility criteria for the incentive subject to further legal input:

- Drivers must have a current valid Hackney Carriage plate/licence
- Drivers must first pay all relevant fees (at the relevant frequencies) before being able to redeem the licensing costs
- Drivers must produce a copy of an official record of ownership of an 0EV or ULEV taxi i.e. V5/log book
- Drivers will be expected to sign an agreement to remain in the trade for three years (if they do not the Council reserves the right to claw back the incentive funds)
- Fees can only be redeemed on ULEV taxis that meet the Council's vehicle licensing definitions i.e. be 100% wheelchair accessible and ULEV (as defined above)
- The fees (once paid initially) can be redeemed up to 90 days after payment was made to the Council.

The Council will reserve the right to deny the release of any redemption fees should it find the requests non-compliant with the eligibility criteria set out. The scheme will strictly operate on a first come first serve basis, however the Council commits to monitoring progress and making any necessary amendments as required in order to maximise the benefits of the scheme that fit with the overall objectives.

Eligibility and validation: Any hackney carriage owner or driver currently licenced with Cardiff Council will be eligible for this scheme and it will be operated on a first come – first served basis. The validation process will most likely be conducted in person, at the Council's licencing office. The validation is expected to be a simple process of checking the driver in question against the Councils database of licensed owners, drivers and vehicles.

Operational finance package for 0EV/ ULEV vehicles: for this scheme, any owner or driver who purchases a 0EV or ULEV Hackney carriage after the date of the implementation of the revised licensing policy will be eligible to receive the funding amount. Once the driver has purchased/leased the vehicle they will provide evidence of the transaction to Shared Regulatory Services (SRS)/ Cardiff Council Licensing Team who will then validate it with the manufacturer.

It is anticipated that this scheme will commence in January 2020, and Cardiff Council will then provide 3 consecutive annual payments of a maximum £1000pa, to the driver. Before each payment the driver must provide evidence that they are still operating the 0EV or ULEV taxi and that it is still licenced by the council. Where possible, this will be provided as benefits rather than as a cash payment, a good example of this is the licencing fee which the council can easily provide free of charge to a 0EV or ULEV owner or driver.

State Aid

CC has identified issues in aiding Hackney carriage drivers in purchasing/leasing a new ULEV taxi. These result from the fact there is currently only one provider of a ULEV taxi and already a government taxi grant in place, which leads to additionally issues as well as possible market distortion. When combined with government support, the amount that ends up being transferred to the taxi company in question could result in State aid issues. Therefore, an approach has been taken which seeks to offset the operational costs of Taxis rather than the purchase cost. A similar scheme is in the process of being implemented by Southampton City

Council and Cardiff Council will seek further confirmation from our legal team to ensure that this approach does not violate State aid regulations.

This proposal does not affect state aid (as the financial value falls below de minimis[52]) and is decoupled from the cost of the vehicles thus not presenting any issues with the General Block Exemptions negotiated by Government on the ULEV vehicle purchase price. Advice from Cardiff Council legal team has confirmed that these proposals do not constitute state aid. The redemption agreements will seek confirmation that operators/ drivers are not in receipt of any other state aid and if so need to declare it for verification.

4.7 Summary of Commercial Case

The current intention is to deliver the majority of elements of the preferred scheme through existing frameworks that are accessible to the Council. This enables the project to be delivered in accordance with primary spending objectives for the project, which is to achieve compliance within the shortest possible time period.

It is also considered the most appropriate way to help ensure the Council manages risks associated with the project, particularly regarding scheme delivery. By utilising existing frameworks it enables the minimising of risks further by utilising contractors that are already familiar with Cardiff, it avoids any lengthy procurement processes and helps to drive down costs and ensure additional programme certainty.

[52] The De Minimis Regulation allows small amounts of aid – less than €200,000 over 3 rolling years – to be given to an undertaking for a wide range of purposes - State Aid: The Basics Guide

Section 5 Financial Case

The financial case establishes if an option is affordable in the first place and the long term financial viability of the scheme.

Any funding gap must be made clear. Potential sources of external funding to meet capital shortfalls should be identified and the key requirements and criteria of those funding bodies stated.

5.1 Funding

Within its latest Interim supplemental plan to the UK plan for tackling roadside nitrogen dioxide concentrations 2017 [53] the Welsh Government has stated that it has allocated over £20 million for an Air Quality Fund through to 2021 to help accelerate compliance with NO_2 limits and improve air quality in Wales. The report further states that this fund will primarily be used to provide on-going support, guidance and finance to enable Cardiff Council (and Caerphilly CBC) to take action to achieve compliance in the shortest possible time. The funding will support work to conduct feasibility studies, implement early measures which help accelerate exposure reduction and deliver the options which will achieve compliance in the shortest possible time.

Within the Minister's letter that accompanied the formal direction it was confirmed that finance would be made available for the production of the feasibility study and for the implementation of the chosen scheme.

In addition to the above funding mechanism, the Council will continue to work collaboratively with Welsh Government officers to identify all available and an appropriate funding mechanisms including transportation funds, to maximise the financial contribution from Welsh Government towards the implementation of any measures.

However, until funding is confirmed the risk remains that the full programme proposed may not be deliverable and the measures may need to be reduced.

5.2 Financial Model

In terms of the costs for the City Centre costs, these have been developed using South East Wales Highways Framework pricing as this framework will be utilised to procure the works as detailed in the commercial case.

For the Clean Bus Technology Fund these costs have been developed using detailed implementation costs provided as part of the original bid made to DfT. These costs have been further estimated to account for an increase in the number of buses to be included.
The WelTAG appraisal guidance states that the lifetime costs of the project to include occurrence, price, source of funding, maintenance liabilities, risk allowances, environmental, social and cultural impacts and externalities. The expenditure forecasts for the measures includes such elements where practicable, and more accurate forecasts will be provided as necessary following appropriate tendering and contract award offers.

[53] Interim Welsh Government supplemental plan to the UK plan for tackling roadside nitrogen dioxide concentrations 2017 July 2018.

5.3 Cost Assumptions

5.3.1 Electric Buses

Cardiff Council, Welsh Government and Cardiff Bus, bid jointly to the Department of Transport (DfT) Ultra Low Emission Bus (ULEB) Grant fund for funding of up to £5.7M for 36 electric buses and associated charging infrastructure. The Grant Funding contributes 75% of the cost difference between the purchase of conventional diesel buses and their electric equivalent and 75% of the capital for the required infrastructure.

In order to meet the balance of the cost difference (25% - £1.8 million), Cabinet have been asked to consider providing this as a commercial loan from the Council, in addition to a sum of £2 million previously requested in order to support the Company's acquisition of vehicles. This is the subject of a separate report to Cabinet.

Owing to state aid issues no further grant funding is possible or being sought for this measure with the costs to be borne by the company as part of its long term fleet replacement programme. Funding has been secured from Department of Transport (DfT), from their ULEB Grant, and thus further funding towards this measure cannot be supplied directly to Cardiff Bus owing to State Aid Issues.

5.3.2 Retro-Fit Scheme for Buses

To assess the impact of such a scheme the report has modelled the impact of retrofitting buses. The costs of implementing such a scheme as been costed based on a historic application made jointly in 2017 by Cardiff Council and Cardiff Bus.

The bid was based on exhaust after emission treatment technology, namely selective catalytic reduction (SCR). Research by Low Carbon Vehicle Partnership (LowCVP)[54] details that this technology can reduce NO_2 emissions by 88% Euro III, 90% Euro IV and **98% for Euro V.** The proposal also included for the implementation of diesel particulate filters (DPFs) which can lead to a >75% reduction in particulate emissions.

The proposal in the FBC is to fund up to 150 buses, on the condition that all operators within Cardiff can apply for the scheme.

As such the following outline cost and expenditure breakdown for this scheme is detailed below in Table 48.

Table 48 - Bus Retrofit Scheme Costs

Diesel Bus Retro Fitting	2019/20 (50 Buses) £	2020/21 (100 Buses) £	150 in total £
Retrofit Costs*	£670,000	£1,340,000	£2,010,000
Telematics and data report for 5 years	£80,000	£160,000	£240,000
	£829920		**Total** £2,250,000

The above expenditure has been split over two financial years.

[54] https://www.lowcvp.org.uk/assets/reports/CVTF_CBTF%20Evaluation%20Study%20-%20FINAL.pdf

However the previous programme indicated potentially 94 buses could be completed over **a 25 week programme** which could allow for the full 150 buses to be completed within a single calendar year. However in discussions with some operators they have indicated that they would initially like to assess the performance and operation of the technology over an initial 3 month test period on a limited number of buses and this will be factored into the implementation timelines.

If the uptake of the retrofit scheme is not sufficient to provide the modelled air quality benefits then the Council will need to assess the possibility of introducing a Low Emission Zone (LEZ) for Buses. This would require buses operating in the LEZ to have minimum emission standard of Euro 6/ equivalent retrofit or ULEV, which would look to increase the uptake of the scheme.
Such a zone would be achieved by applying to the Traffic Commissioner to issue a Traffic Regulation Condition (TRC) which applies to the license of bus operators providing services in Cardiff. A TRC would be issued under the Regulation 7 of the Transport Act 1985[55], whereby Regulation 7(4) states that if the traffic commissioner is satisfied, 'after considering the traffic in the area in question that such conditions are required or are likely to be required in order to ….(c) reduce or limit …air pollution.

The introduction of such zones has been undertaken in a number of Cities in the UK outside of London, including Oxford, Brighton and Glasgow.

Alternatively the Council will work with local operators on the possibility of establishing a Quality Partnership Scheme (QPS) under Section 114 of the Transport Act 2000. Such schemes can be voluntary or statutory and provides looks to improve facilities and services in an agreed area of operation. As part of the QPS, it is possible to stipulate minimum emissions standards that buses operating in the area of QPS would be required to meet, i.e., Euro 6 retrofit or ULEV.

5.3.3 Taxi Licensing Policy and Mitigation Measures

On the 5th March 2019 the Public Protection Committee agreed for Shared Regulatory Services to consult on the proposals to amend the Council's taxi licensing policy which would see the introduction of new emissions and age requirements for the granting of new licenses and/ or change of vehicle applications on new existing licenses. **The proposals[56] would require that any vehicle included on the application for a new grant is a minimum Euro 6 emission standard (petrol and diesel) as part of the license application. The same emission standard would also apply for any change of vehicle on an existing license.**

Whilst it is not possible to predict the outcome of the consultation process on the revised policy, the Public Protection Committee will be asked to approve the revisions of the Councils licensing policy, with an implementation date to be agreed. Whilst there is no direct cost the Council for implementing the revised license conditions, it could be argued that Council's new taxi strategy to set age and emissions criteria for licensing for private hire and hackney carriages could place a financial burden on drivers and operators licensed within Cardiff. This burden is not faced by taxis licensed outside of Cardiff and they are free to compete for trade alongside Cardiff licensed taxis. This potential could see Cardiff taxis placed at a financial disadvantage. The economic assessment has included the provision of mitigating measures

[55] https://www.legislation.gov.uk/ukpga/1985/67/contents
[56] Public Protection Committee 5th March 2019 Item 5 Update To The Age, Emission And Testing Requirements Of Hackney Carriage And Private Hire Vehicles

for the taxi trade. A number of Councils in the UK have already introduced similar vehicle emission standards on taxis, but in doing so they have worked to assist the taxi trade by offering incentive schemes.

As detailed in the commercial case it is proposed, subject to approval from Welsh Government, that the Council will introduce an incentive scheme for the first 620 vehicles ~30% of the licensed fleet, who licence a new ULEV taxi with the authority to cover a proportion of the running costs of these vehicles. A maximum grant fund of £3000 will be offered over a 3 year period, subject to the conditions of grant being met.

The scheme will be based on upon the similar successful schemes funded by the UK Government for a number of local authorities in England, including Birmingham, Nottingham and Southampton who offer taxi licensing redemption schemes. The scheme will be subject to strict criteria and only open to drivers/ operators who license taxis within Cardiff and agree to do so for a minimum of 3 years. The full details of the scheme will be developed in conjunction with Shared Regulatory Services, and will be finalised as part of the report to Public Protection Committee as part of the approval to agree the licensing policy amendments.

The total cost of this scheme is anticipated to be £1,860,000. The following spend profile for the initial grant scheme has been estimated in Table 49.

Table 49 - Taxi Incentive Grant Scheme Spend Forecast

Potential Grants	19/20	20/21	21/22	Total Initial Grant Costs
£3000/ 3 years – 620 taxis	£620,000	£620,000,	£620,000	£1,860,000

However, Cardiff Council would like to ensure that the grant scheme remains in place until such a time that the target of 30% ULEV is achieved. Further in order to encourage wider uptake of EV/ ULEV for the taxi trade the Council will work with Welsh Government to establish whether a wider, possibly national scheme, to support the switch of licensed vehicles to EV/ ULEV can be implemented.

5.3.4 City Centre Transport Improvement Scheme

The main purpose of these schemes is to allow for better and more efficient movement of public transport (buses) and increase active travel capacity in the City Centre. Such schemes will also look to reduce highways capacity for private vehicles which will is intended to be a catalyst for increase modal shift to public and active travel. It must be noted that these schemes, are currently being taken through separate WelTAG assessments and therefore could be subject to change as part of this process and any required associated processes, such as public consultation and Traffic Regulation Orders. The three schemes are proposed are:

City Centre West (CCW)

The main aim of this scheme is to accommodate the new Transport Interchange and Central Square Development, whilst also Improving Air Quality within the City Centre AQMA. This will be achieved through removing through-traffic from Westgate Street and installing a new highway layout that will improve and connect the current bus network with the new Interchange, Central Square, Central Station and the City Centre Enterprise Zone. In addition, the scheme will offer improved safety for pedestrians via improved pedestrian crossing facilities, 20mph speed limits and an improvement to the pedestrian environment outside of the national stadium. The scheme will also install a network of stepped cycle tracks to connect the area with the proposed cycle superhighway on Castle Street and the Taff Trail routes.

City Centre North (CCN)
The main aim of this scheme is to bring Castle Street into Air Quality compliance by 2021 and install a two way dedicated cycleway along its length. The installation of the cycle lane and the reduction in highway space will allow for traffic to be reduced by ~29%. Improved pedestrian crossings with countdown timers will also provide safety improvements for pedestrians.

Eastside Phase 1
The main aim of this scheme is to provide a new dynamic for the bus network, whilst connecting cycle superhighway and improving the pedestrian environment outside of Queen Street Station. This will be achieved through providing bus priority measure throughout the Station Terrace and Churchill Way areas that will provide new routes for buses, taking them away from the City Centre AQMA and closer to key areas such as Queen Street Station and the shopping district. The new bus routing system is also key to allowing the Interchange to be accessed from its south entrance, and work effectively on major event days. A cycle superhighway will be installed to connect the east of the city centre with the City Centre Enterprise Zone, and join up all the proposed cycle superhighway routes. Pedestrian improvements on Dumfries Place and Station Terrace will also improve safety for pedestrians and improve connections to Queen Street Station and the City Centre Enterprise Zone.

The expenditure forecasts for the City Centre Transport Improvement Schemes are detailed in the following tables.

Table 50 - City Centre West Scheme Expenditure Forecast

CCW	£000's	£000's	£000's	£000's
	Pre19/20	19/20	20/21	total
Surveys/Modelling	461	-		
Design	100	104		
Land Purchase				
Accommodation Works (WelTAG)		152	272	
Construction		1,600	4,400	
Project Mgmt.		130	381	
Monitoring Evaluation		-	20	
Promotion		5	5	
Gross Totals	561	1,991	5,078	**7,630**

Table 51 - City Centre North Scheme Expenditure Forecast

CCN	£000's	£000's	£000's	£000's	£000's	£000's
	Pre19/20	**19/20**	**20/21**	**2021/22**	**22**	total
Surveys/Modelling	48	50	-	50		
Design	86	9	9	80		
Land Purchase						

Accommodation Works (WelTAG)		53	53		118	
Construction		3,000			3,000	
Project Mgmt.		127	127		255	
Monitoring Evaluation			10		10	
Promotion		5	5		10	
Gross Totals	£134	£3,244	£204	£130	3,393	**7,105**

Table 52 - Eastside Phs 1 Scheme Expenditure Forecast

Eastside Phase 1	£000's	£000's	£000's	£000's
	Pre19/20	**19/20**	**20/21**	**total**
Surveys/Modelling	81	330	20	
Design	130	157	0	
Land Purchase	0	0	0	
Accommodation Works (WelTAG)	44	0	108	
Construction		0	3,000	
Project Mgmt.		23	243	
Monitoring Evaluation		0	0	
Promotion		0	10	
Gross Totals	255	510	3,381	**4,146**

The total outline cost for the three schemes is **£18.9M.** In terms of the above, the Transport Planning Policy and Strategy Team have already been successful in bidding for **£2.75m** from the Local Travel Fund (LTF) for the financial year 2019-20, enabling it to begin construction on City Centre West and North Phase 1 within year. This reduces the funding requirements for the City Centre Scheme to **£15.2m** inclusive of previous 18/19 in year expenditure accounted for.

The initial LTF bid for the schemes was based on a 5 year expenditure profile so further funding to complete the schemes and further LTF funding for expenditure in 20/21 may be provided. However it will be imperative in terms of achieving compliance that the City Centre North (Castle Street) Scheme is fully funded and thus it is essential that the remaining **£5.725m** to complete this scheme is confirmed as part of the Clean Air Fund.

The implementation of the schemes are extremely challenging in terms of full completion by the end of 2021 to demonstrate compliance. As such it is imperative that the Council has confidence on available funding in order to that appropriate procurement procedures can commence in order that contracts for design and build can be awarded at the earliest opportunity, with the aim of construction works **commencing no later than January 2020**.

5.3.5 Active Travel Measures

For the expansion of 20mph area a funding bid of £2m was made to the LTF and only £500k of this has been awarded. As such in order to complete the wider 20mph area/Active Travel role out within Grangetown which will provide further mitigation in relation to any impacts of the wider City Centre Schemes.

Whilst the completion and completion of the CS1 to University Hospital Wales (UHW) has been modelled, this measure will continue to be bid for from the Active Travel Fund and thus has been removed from the funding requirements of the Clean Air Plan.

Table 53 - Expenditure Forecast for the 20 Mph Areas

20mph Areas	£000s Pre 19/20	£000s 2019/20	£000s Total
Surveys	3	6	9
Design	27	124	151
Land Purchase	0	0	0
Accommodation Works	0	7	7
Construction	160	1,021	1,181
Project Management	0	103	103
Monitoring and Evaluation	0	13	13
Promotion	0	4	4
GROSS TOTAL	**190**	**1,278**	**1,468**

5.3.6 Funding Summary

The projected costs estimated for the FBC costs to implement the package of measures as a preferred option is summarised below in Table 54.

Table 54 - Final Preferred Package of Measures Costs

Measure	Est. Funding Requirements £M
Bus Retrofit	£2.25m
Taxi Mitigation Schemes	£1.86m
City Centre Schemes	£15.2m**
Active Travel 20 mph areas	£1.28m
	Total: **£20.59m**

*Based on 620 £3k EV Grant. ** Preference of £5.725 being awarded from Clean Air Fund to complete Castle Street works which are aimed at achieving

The revised costs for the Full Business Case are significantly lower than the initial figure of £32.5m in the OBC. The main reasons for this is as follows:

- Approved funding from Local Travel Fund removed from City Centre Schemes;
- Removal of completion of CS1 as future Active Travel Bids will be made to secure the completion of this infrastructure;
- Refined taxi mitigation package.

As previously stated in terms of the City Centre Schemes priority should be given to the City Centre North Phase 1 scheme as this scheme contributes significantly to reducing NO_2 levels in pursuance of achieving compliance with the limit value.

5.3.7 Monitoring and Evaluation

The process of monitoring and evaluating projects is designed to ensure that lessons learned are fed back into the decision making process, ensuring that continual improvement and best practice is applied to current and future transport projects.

Cardiff Council identifies that the key outcomes are;

- **Compliant and improved levels of air quality**- The proposed package of mitigation measures does not only achieve compliant in the localised area of exceedance on Castle Street, it is expected that citywide air quality levels will improve, particularly within the established local air quality management areas;
- **Improved public health**;
- **Improved transport management systems**- Changes in journey patterns due to traffic redistribution without creating new sites of exceedance;
- **Reduced vehicle trips and vehicular emissions at the site of exceedance-** The proposed package of measures will lead to less polluting buses and taxis; and
- **Overall/ Citywide reduction in vehicular trips generated-** Caused by a greater proportion of low emission, active travel and sustainable transport trips.

A monitoring and evaluation plan will be developed to ascertain and ensure that the likelihood of achieving the key outcomes is achievable and the benefits realised. The monitoring and evaluation plan is a supporting mechanism that measures and evaluates the project during and post completion.

5.3.7.1 Air Quality Monitoring and Modelling

As part of the primary outcome it will be important to demonstrate the actual effectiveness that the measures will provide in terms of NO_2 and other emission reductions. Cardiff Council does operate an existing network to monitor traffic data and air quality. This existing network will be supplemented with new monitoring stations to ensure that a robust data set is maintained. In order to demonstrate that compliance will be achieved on Castle Street, it is proposed that a real-time monitoring station, equivalent to AURN site standards be established within this City Centre location, on Castle Street. Adding to this automated principle of air quality monitoring the Council will appoint and implement five indicative real-time monitors to assess and monitor any displacement effects of the proposed measures on peripheral areas, and in particular the City Centre AQMA. The described monitoring enhancements will look to be implemented as early as possible, expected to be gathering data throughout the implementation phase of the proposed measures to assess the impact of the work being carried out and also to establish whether there is any early behaviour change. This early behavioural change analysis is likely to be in the period late 2019 to early 2020.

The post project of evaluation will establish whether Cardiff Council achieves compliance with the air quality objectives. This will be demonstrated via annual average datasets covering the period January 2021 to December 2021. Therefore it is likely that this analysis will be undertaken in January 2022.

The location of the proposed monitors are detailed in **Figure 16** and the proposed costs for implementing the monitoring network is detailed in Table 55 and **Table 56**.

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Figure 16 - Locations of Proposed Air Quality Monitoring Network

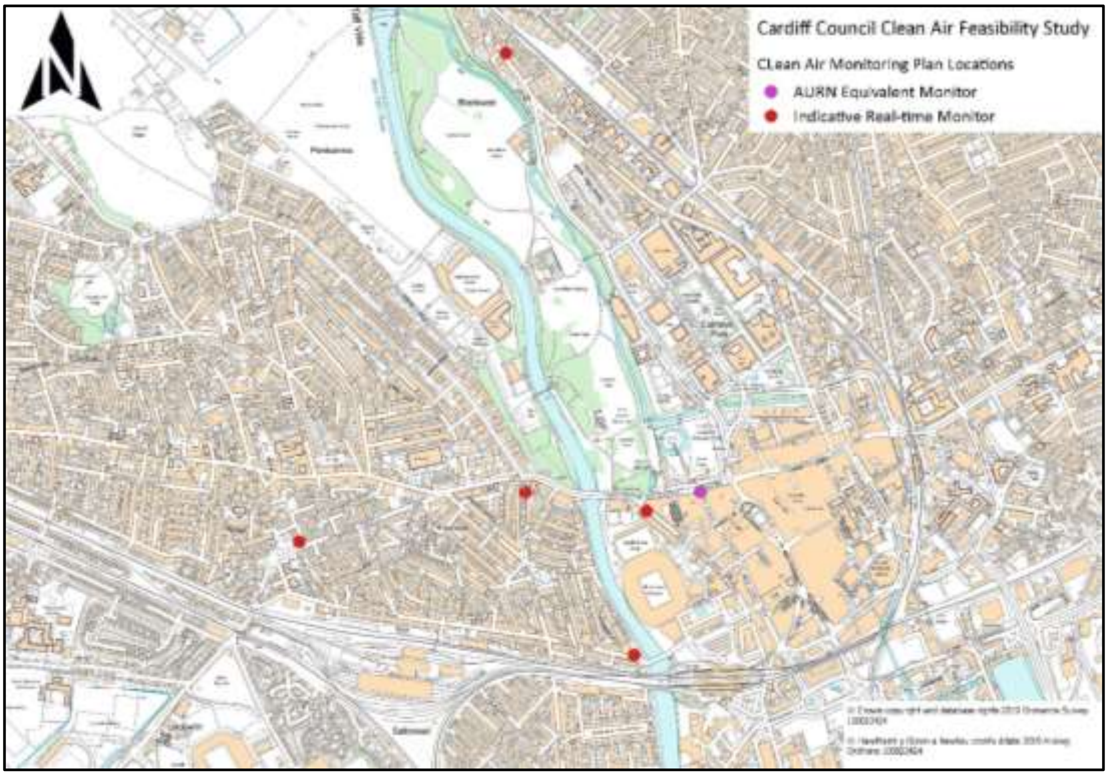


Table 55 - Cost Estimates for an Equivalent AURN Monitoring Station

Castle Street Automated Monitoring Station	2019/20	2020/21	2021/22	
Equipment Purchase and Installation	£26,000	£0	£0	
Planning and Construction	£4,000	£0	£0	
Service and Maintenance	£2,600	£2,600	£2,600	
Data Handling	£1,950	£1,950	£1,950	
Utility Charges	£750	£765	£765	
Project Mgmt.	£350	£225	£225	
Monitoring Evaluation	£550	£560	£570	
Promotion	£250	£0	£0	
Gross Total	£36,450	£6,090	£6,090	**£48,630**

Table 56 - Cost Estimate for Additional Near Real-time Air Quality Analysers

Castle Street Automated Monitoring Station	2019/20	2020/21	2021/22	
Equipment Purchase and Installation	£35,795	£0	£0	
Planning and Construction	£112	£0	£0	
Service and Maintenance	£0	£3,600	£0	
Data Handling (Server Fee)	£3,000	£2,400	£2,400	
Utility Charges	£0	£0	£0	
Project Mgmt.	£350	£360	£350	
Monitoring Evaluation	£155	£160	£165	
Promotion	£250	£0	£0	
Gross Total	£39,662	£6,520	£2,915	**£49,097**

To complement the monitoring data and to get a full picture of air quality across the city it is proposed to do further air quality modelling before and after the schemes are implemented, using updated activity data as collected below. This will insure the fullest possible picture of air quality across the city as a result of the measures.

5.3.7.2 Bus and Taxi Data

The key data set here will be collecting up to date fleet data from the bus operators and taxis (through licencing) to track the implementation of the measures and evolution of the fleet.

In addition, it would be ideal to then assess the change in emission from these vehicles that is being generated by the changes to the fleet. To some degree this will be picked up in the air quality modelling as the new fleet data will be used to update the emissions from these vehicles for the model.

The above could be further enhanced, by undertaking real-world emission monitoring to measure the changes in bus and taxi emissions, something which has been done in London for their bus retrofit programme. A central location would be chosen with high bus and taxi flows to maximise capture of vehicles in the fleet. A before and after survey would be carried out to assess the real emissions benefit of the retrofit systems for buses and the switch to Euro 6 and ULEV in the taxi fleet.

5.3.7.3 City Centre Schemes

The key data here will be collection of traffic count data using ATC and/or ANPR to assess the changes in traffic flows and composition of the local fleet. Ideally ANPR would be used as part of this as this data could be then be used to update fleet characteristics in the air quality model in terms of Euro Standards and so on. Ideally to compare our baseline conditions it may be beneficial to re-run the ANPR surveys that were undertaken for the feasibility work so that the data can be further utilised in any further air quality monitoring.

5.3.7.4 Active Travel

In this case, there would be a need to collect travel data in the areas affected to assess the mode shift that has been achieved and how this compares with the original assumptions made in our modelling.

Further surveys will also be conducted to assess whether the measures have results in increased patronage on public transport and increase of active travel modes. It is likely that the Cardiff Research Centre in Cardiff Council will play an integral part in this work and we develop specific questions to capture robust data.

The above monitoring data will be collated appropriately and a specific monitoring and evaluation report submitted initial on an annual basis to Welsh Government for review.

5.3.7.5 Public Health Outcomes

Utilising methods recommended by the Committee on the Medical Effects of Air Pollution (2018)[57], modelled air pollution concentrations can be used to estimate health impacts (using the all-cause mortality health outcome) before, and over the course of, implementing the clean air plan. Comparisons can be made with baseline 2017 estimates to quantify air pollution and associated health status changes over the long-term (at the local authority level). Consideration can also be given to using short-term health impact quantification methods, where appropriate.

The Council will work collaboratively with Public Health Wales to consider using a model such as those developed by the World Health Organisation[58] and Public Health England[59]. These models replicate real life as closely as possible, using national population and disease statistics to test the long-term impact of the proposed air pollution interventions on future health and other outcomes such as:

- the estimated impact on air pollution related diseases;
- proportion of people living in areas of relative ‘low’, ‘moderate’ or ‘high’ pollution;
- impacts to susceptible groups (e.g. age and deprivation); and
- NHS cost of air pollution.

Initially this will be focused on NO_2 but the methodology could also be applied to other key pollutants such as fine particulate matter (PM2.5).

However, as acknowledged by the UK Committee on the Medical Effects of Air Pollution (COMEAP), there is uncertainty in air pollution-related health quantification assessment methodologies, because of the following:

- Air pollutants exist as a complex mixture and effects attributed to one pollutant may also be attributed to another. COMEAP (2018) stated “it is highly likely that there is an overlap between the associations for NO2 and PM2.5, although there are considerable uncertainties in estimating the size of this overlap”;

- The health outcomes are also linked with several other risk factors; it is not possible to attribute any health impact changes directly to air quality improvement; however lower air pollution concentrations are linked to lower health risks.The study period is short, and the exposure effect coefficients are based on life time exposure;

[57] https://www.gov.uk/government/publications/nitrogen-dioxide-effects-on-mortality
[58] http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/activities/airq-software-tool-for-health-risk-assessment-of-air-pollution
[59] https://www.gov.uk/government/publications/air-pollution-a-tool-to-estimate-healthcare-costs

- The risk assessment will rely on modelling to estimate exposure, it is not possible to be certain that the estimated exposure coincides with the actual ambient concentrations in a given location or for a given individual;

- Practical considerations may require the use of a simplified model, which can lead to increased uncertainty.

The outcomes of this assessment will be included in the Monitoring and Evaluation Report, although depending on the nature of the outcomes of the assessment a separate Public Health Outcome report may be preferred. An additional cost of £150k has been estimated to enable the appropriate modelling and reporting requirements for the Monitoring and Evaluation Plan to be completed as detailed above. This figure has been estimated from inputs from our consultants but could be subject to change depending on the full extent of the final reports.

5.4 Budget and Risk Management

Costs will be managed by ensuring all procurement follows the procurement strategy outlined in the Commercial Case. The assessment of tenders through this process will be based on both quality and price to ensure value for money.

The budget management responsibility will fall to the overall Project Manager, and this specifically relates to the City Centre Transport Improvements and 20 mph zones.

5.5 Resources

Resource (internal staff) Costs are estimated based on Cardiff Council 2018/19 pay scales accounting for inflation and relevant on costs in subsequent years (2% assumed) applied to an assessment of the level of staffing resource required to progress the initiatives in this Business Case. The grades listed have been estimated based on the proposed, but may be subject to change as the projects move forward. The resources are presented below;

Table 57 - Staff Costs for Resources

Role Description	Grade	Duration/ Recruitment	Est Cost over 2 years £
Director Planning Transport and Environment - To provide Senior management decisions and oversight to the project team.	Director	Existing - 2 years	£24,000
Operational Manager (OM1) - Additional Snr Management support and oversight for the project	OM1 -	Existing - 2 years	£20,000
Clean Air Cardiff (CAC) – Programme Manager - To promote, administer and contract manage and evaluate the measures. Facilitate business change amongst participants. Support Specialist Officers. To deliver the monitoring and evaluation activities. Contract manage external support services. Collate all associated reporting and updating to Clean Air Strategy Group (Project Board). Contract manage Clean Bus Fund and Taxi Incentive Scheme (in conjunction with SRS). Line management responsibility for the CAC team	OM2	Currently on Secondment Funded from Feasibility Study – required for 2 years for Implementation and Evaluation.	£146,000

Role Description	Grade	Duration/ Recruitment	Est Cost over 2 years £
CAC Specialist Services Officers x 2 - To manage the implementation of the measures to ensure active uptake and engagement with stakeholders. To implement the evaluation programmes in terms of air quality monitoring and development of annual reports.	Cardiff Grade 8	New resource temporary 24 month contract	£205k
			Total: **£395,000**

5.6 Other Funding Options

The Council will need to continue to work collaboratively with Welsh Government officers to maximise the financial contribution from the Welsh Government towards the implementation of the measures. Until funding is confirmed the risk remains that the full programme proposed may not be deliverable and the schemes may need to be reduced or removed to match the Welsh Government funding that will be available.

However, the Council will explore all other funding opportunities to obtain additional resources to implement the measures including associated bids to the Local Transport and Active Travel Funds, Section 106 Planning contributions, and City Deal.

5.7 Final Cost Summary

The full costs of the Councils Plan is summarised below in Table 58 and includes all costs for implementation of the measures (existing funding awards removed), resource costs for staff and costs for monitoring and evaluation.

Table 58 - Estimated Full Cost of Plan

Measure	Est. Funding Requirements £M
Bus Retrofit	£2.25m
Taxi Mitigation Schemes	£1.86m
City Centre Schemes	£15.2m**
Active Travel 20 mph areas	£1.28m
Staff Resources	£0.395
Monitoring and Evaluation	£0.25m
	Total: **£21.2m**

Section 6 Management Case

6.1 Introduction

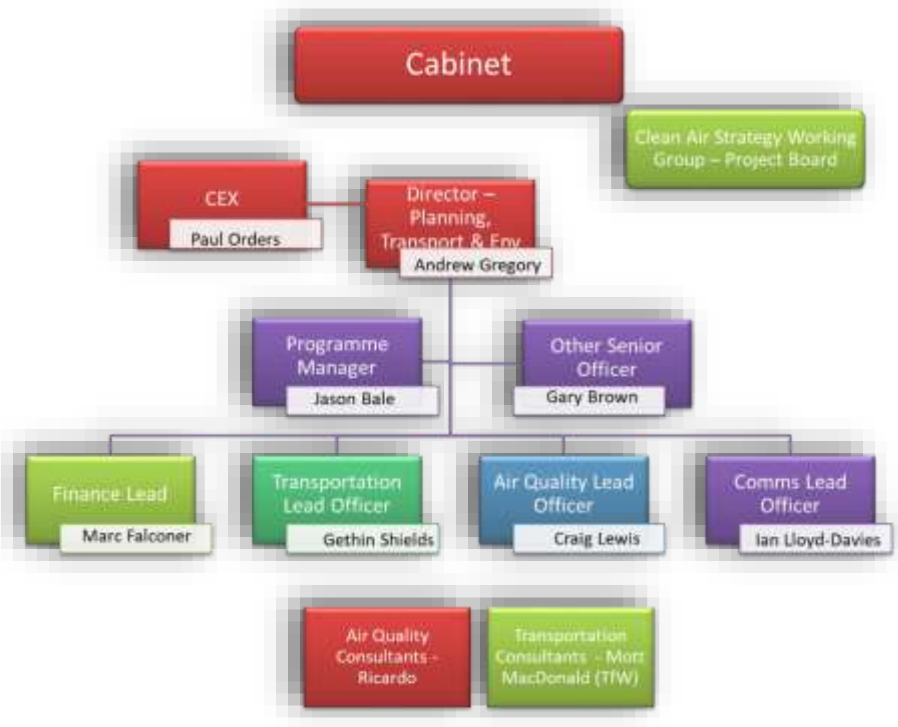
The purpose of the Management Case within this FBC is to detail the project management strategy, roles, and governance structure to demonstrate how the preferred option will be delivered successfully. In accordance with the Inception package of JAQUs guidance the FBC considers the following;

- Update of project plan, including timescales and ownership;
- Updated change management strategy, as well as update to role and responsibilities,
- Outline the arrangements required to ensure successful delivery of the scheme;
- Benefits realisation should be set out here for the identification of potential benefits, modelling and tracking as well as a risk management strategy and risk mitigation.

6.2 Clean Air Cardiff Project Team

The current Clean Air Cardiff Project Team reports on a monthly basis to the Clean Air Strategy Group which ultimately reports to the Cabinet. The Clean Air Strategy Group is chaired by the **Leader of the Council**, and its membership includes Senior Management Team representatives, including the Chief Executive and the following relevant Cabinet Members:

- Cabinet Member for Strategic Planning & Transport
- Cabinet Member for Clean Streets, Recycling and Environment
- Cabinet Member for Social Care, Health & Well-being;



In addition the Council has been working collaboratively with Welsh Government throughout the whole feasibility study process.

6.3 Project Plan

In terms of the timescales for the implementation of the measures and delivery is presented in Figure 17. It should be noted that in terms of the City Centre Schemes these will be subject to detailed project plans that will be produced by the appointed contractor following the tender process and contract award. The Clean Air Project team will share these with Welsh Government once available as part of the Implementation Plan.

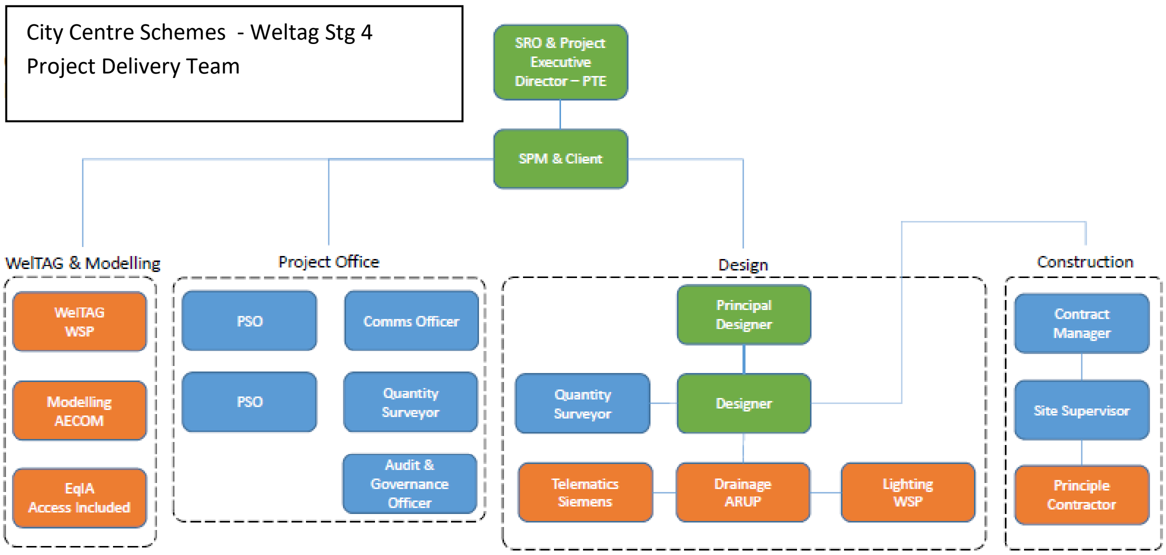
6.4 City Centre Transport Improvements and Active Travel Schemes

The City Centre Schemes will be run in accordance with the Council's Project Quality Assurance (PQA) scheme which is Cardiff Council's Project and Programme Management Standard and is based on PRINCE2 (PRojects IN Controlled Environments) and MSP (Managing Successful Programmes) which are the methodologies approved by government for public sector projects. PQA provides guidance on how the Council will manage projects, recognising that projects are:

- Change focussed
- Unique
- Composed of inter-dependent activities
- Carried out by people who don't normally work together
- Temporary, with defined start and end dates
- Established to achieve a specific outcome

The contract management elements of any work related to the City Centre Transport Improvement will be overseen by the Head of Transport. The Head of Transport also attends Clean Air Strategy Group and will ensure ensuring appropriate oversight of any works undertaken by contractors directly related to Strategic Transport. The project delivery team is detailed below and this will be further updated on contract award for the schemes.

A tailored Prince II and APM format has been used during the research phase; this will continue to be used alongside Client Design & Management Regulations CDM (2015) during the detailed design and construction process.



6.4.1 Statutory Processes and Planning Consents

The City Centre Schemes and Active will be progressed through the Traffic Regulation Order process which will take approximately 6-9 months. The schemes do not need to take account of any planning consents, as planning permission will not be required.

The remaining measures are not required to follow any statutory processes.

6.5 Financial Management

6.5.1 Financial Reporting

The Project Manager will be responsible for undertaking regular financial reporting to inform the Programme Board of the projects progress and performance. A Project Initiation Document will be developed to provide a firm foundation for the initiation of the project. It will set out the direction and scope of the project, and form the 'contract' between the Project Team, Project Manager, Transport Delivery Board and the Programme Board.

Following initiation, the Project Manager will produce monthly highlight reports which will be submitted to the Project Delivery Board.

Scrutiny and oversight of the projects financial management will be provided by the Programme Team.

6.5.2 Variation Monitoring

As with all large scale projects it is expected that elements of the agreed plan, budget, or scope will need to be varied at some point during the project cycle. It is important that means of controlling any variations are signed offer before being implemented so that they can be dealt with simply and at the correct level.

A variation to the project will be identified through the monthly progress reports where activities are not being carried out according to the plan or for the agreed cost, or an issue has arisen to affect the scope. All variation will be recorded on a variation request log that will be used to specify why the change has come about, what actions are proposed to counter it, and at what level decision-making sits.

A set of tolerances will be determined, so that each level of management in the project has the defined authority to agree certain variations before having to refer to a higher level. The agreed tolerances will be recorded in the Project Initiation Document, as will the period within which variations are cumulative.

Variations that do not affect the plan or the budget by more than is reported in one month will likely sit within the tolerance of the project manager. Although additional decision-making will not be required, all such variations will be recorded on the monthly progress report and an entry will be made on the variation request log.

Variations of a higher tolerance will be clearly brought to the attention of the Project Delivery Board (PDB) in the finances section of the progress report. This will allow a discussion to take place and a way to proceed be agreed. Larger variations, which exceed the tolerance of the PDB, will need to be taken to a higher level of decision-making beyond the PDB.

6.6 Implementation Plan

An outline implementation plan, for the measures of the preferred option is provided in Figure 17.

In terms of the City Centre Transport Improvement Schemes, these will be subject to additional more detailed plans that will be provided by the appropriately appointed contractors following completion of the tender process and approval from the project board and will be shared accordingly with Welsh Government, once available.

With regards to the bus measures more detailed plans will be provided on commencement of procurement processes and appointment of suppliers.

6.7 Risk Management

Risks will be tracked in accordance with the Council's corporate risk management principles, which draw upon the PRINCE2 methodology. This strategy requires the identification and recording of risks, an evaluation of their likelihood and any mitigation actions. This approach ensures that all risks are captured and processed in a consistent manner. The risk register is attached in Appendix D, and includes risks that relate to political, financial and operational issues. Without mitigation, these could result in increased costs to the programme, reductions in the quality of outputs and slippages in timelines, all affecting the overall benefits and outcomes the business case seeks to deliver. Ownership of the risk register falls with the Programme Manager. These risks will be subject to on-going monitoring and mitigated through effective programme management and partnership working.

With regards to the City Centre Transport schemes under the terms of the South East & Mid Wales Highways Framework a scheme specific register will be prepared and priced for each contract at pre-tender preparation stage. The pre-tender estimate and the risk allowance should be used to determine both the Contracting Authority's budget for the scheme and to determine the appropriate level of risk management .

All project members continue to rigorously monitor risk, in accordance with the Council's accepted approach to risk management. High level risks that cannot be managed at a team level will be escalated to the project board for assessment and review. Welsh Government will also continue to be informed of risks that have the potential to impact on the delivery of the scheme, as the project moves forward to implementation.

A project risk register is reviewed by all members of the project team, project board and corporate project board on a regular basis, and appropriate action taken, as required. Included in Appendix 3 is an overview of the risk register for the project, as identified at the time of the FBC submission. As explained in Section 5.7.2, risk owners identified against each item in the register.

6.8 Benefits Realisation

The project will run benefit update meetings with the Clean Air Strategy Group every quarter to monitor the realisation of the projects benefits, until such time as all benefits are realised. It will be the responsibility of the Clean Air Cardiff Programme Manager to arrange and facilitate these meetings and to gather evidence from the monitoring and evaluation work to feed into this review.

Should any issues be identified with benefit realisation, a report will be compiled with recommendations to the Clean Air Strategy Group on how to address any concerns or problems.

Update reports will also be provided to the Clean Air Strategy Group to brief them on the progress of the project. The key benefits register can be found below in Table 59.

Table 59 - Benefits Register

		Measurement		
Benefit	**Description**	**How**	**When**	**Baseline**
EU Ambient Air Quality Directive Compliance in Cardiff agglomeration zone	Improved NO_2 concentrations bring about compliance with EU AQ Directive	Local NO_2 monitoring and modelling	Annually or otherwise agreed with Welsh Government as part of Monitoring and Evaluation Report	Reported in AQ Review and Assessment. Baseline exceeding EU AAQD. Preferred Option modelled to show compliance by 2021.
Compliance with LAQM objectives	Improved NO2 concentrations bring about compliance with LAQM	Local NO2 monitoring and modelling	Monitoring and Evaluation Report	Reported in AQ Review and Assessment. Baseline compliance achieved at LAQM relevant receptors.
Public health improvements	Reduced emissions and achieving EU AAQD limit value will result in health benefits.	Using methods recommended by the Committee on the Medical Effects of Air Pollution (2018), modelled air pollution concentrations can be used to estimate health impacts (using the all-cause mortality health outcome) before, and over the course of, implementing the clean air plan. Comparisons can be made with baseline 2017 estimates to quantify air pollution and associated health status changes over the long-term (at the local authority level). Consideration can also be given to using short-term health impact quantification methods, where appropriate.	Monitoring and Evaluation Report, although a specific Public Health Outcomes Report may be produced.	2017 Baseline date from PHW
Emissions reductions in Cardiff	Uptake of cleaner vehicles and retrofit of older buses will result in emissions reductions of NOx and other pollutants.	Annual emissions of NOx (and other pollutants) within Cardiff	Monitoring and Evaluation Report	Ricardo air quality modelling for NOx and PM estimated emissions reductions - demonstrate emission Reductions.
Increase Patronage of Public Transport Particularly Buses	The prioritisation and improvements in the City Centre should facilitate modal shift to public transport. This will be further improved by the potential interest from Electric Buses.	Assessment of patronage data of public transport and particular routes where Electric Buses will operate	Monitoring and Evaluation Report and Cardiff Annual Travel Survey	Use of 2017 Cardiff Travel Survey data.

		Measurement		
Benefit	**Description**	**How**	**When**	**Baseline**
Increase in Active Travel Journeys	The implementation of high quality cycle lanes that connect Primary Cycleways should increase mode shift to cycling	Undertake dedicate Active Travel Counts on completion of scheme	Monitoring and Evaluation Report and Cardiff Annual Travel Survey	Use of existing/or pre-construction active travel rates in City Centre and wider area of Cardiff.
Improved Pedestrian safety	Use of tabled crossings, additional and wider crossings, countdown timers and 20mph speed limits.	Correlation of all pedestrian accident data in location of schemes.	Monitoring and Evaluation Report	Baseline pedestrian accident data, likely 2018/19.
Noise, accidents and congestion reductions	Implementation of Electric buses and removal of highways capacity	Monitoring and evaluation plan to include estimates of noise, congestion, accidents savings delivered.	Monitoring and Evaluation Report	Qualitative assessment of options impacts only. Business as usual not Qualitatively assessed. Improvements in opex/fuel/GHG savings based on business as usual, therefore assuming PO is improvement.

Figure 17 - Implementation Plan of Preferred Option

Electric Buses

Electric Buses - the below implentation will be fully confirmed upon orders being placed	2019		2020				2021			
	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
Procurement and Installation of Charging Infrastructure			8 months							
Procurement and Delivery Initial 12 Buses				8 mothns						
Procurement and Delivery of Second Order ~24 Buses							12-18 months			

Cardiff Clean Bus Technology Fund

Cardiff Clean Bus Technology Fund	Duration	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20
CC Develop Grant Application and Conditions of Grant Documentation	8 weeks																		
WG Funding Awarded	TBC																		
Invite Operators to Apply for Funding with details of Vehicles	31-Aug																		
Bid Submission Window for Operators	8 weeks																		
Bus Operators Submit Bids	1 Day 31st Oct																		
CC Assess Bids	max 5 days																		
Outcome of Awards notified to Supplier	1 day																		
Operators Notify/ Appoint Suppliers	1 day																		
Quarterly Progress Report	1 day																		
Suppliers Check Vehicles	2 weeks																		
Suppliers Order Necessary Equipment	6-8 weeks																		
Initial Trial Period (if necessary)	12 weeks																		
1st Stage Retrofits ~50 Vehicles	12 weeks																		
Testing Telematics	4 weeks																		
Quarterly Progress Report	1 day																		
2nd Stage Retrofit 100 vehicles	24 weeks																		
Testing Telematics	12-14 weeks																		
Quarterly Progress Reports	1 day																		
Monitoring and Evaluation	ongoing																		

Taxi Licensing and Mitigation Schemes

Taxi Policy and Mitigation Scheme	2019				2020				2021				2022			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Completed Consultation																
Public Protection Committee Recommendation																
Development and finalisation of Grant Scheme with legal apporval																
Implemnetaiton of Scheme																
Monitoring and Evaluation of Scheme																

City Centre Schemes Construction Phases

	2020												2021																
	Q4			Q1			Q2			Q3			Q4			Q1			Q2			Q3			Q4			Q1	
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Central Square																													
Westagate Street																													
Castle Street																													
Boulevard De Nantes																													
City Centre East																													

Active Travel Schemes

Avondale Road, Corporation Road **traffic calming and zebra crossings 2019/20** **Programme**	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Finalise concept design														
Ward member and public consultation														
Detailed design														
Traffic Regulation Order process *if required*														
Tender and procurement														
Construction														
Penarth Road **zebra crossing 2019/20** **Programme**	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Finalise concept design														
Ward member and public consultation														
Detailed design														
Traffic Regulation Order process *if required*														
Tender and procurement														

Construction														
St.Patricks Primary School SSZ **traffic calming and zebra crossing 2019/20** **Programme**	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Finalise concept design														
Ward member and public consultation														
Detailed design														
Traffic Regulation Order process *if required*														
Tender and procurement														
Construction														

Section 7 Summary and Next Steps

7.1 Result on the Assessment of the Preferred Option

Localised air quality modelling and transport modelling was undertaken to quantify the impact of the of the preferred option of a package of non-charging measures in terms of whether compliance could be achieved by 2021. As detailed in the Initial Plan baseline assessment shows that by 2021 only Castle Street would breach the EU limit value for NO_2 with concentrations of 41.1 $\mu g/m^3$ being predicted.

The preferred options demonstrates that significant improvements to in NO_2 concentrations will be achieved, with concentrations on Castle Street modelled to be **31.9 $\mu g/m^3$**, and demonstrates that the measures can achieve compliance with the EU Limit value for NO_2 can in the shortest possible time.

In addition to achieving compliance on Castle Street, the impact of the package of measures has also been modelled at local air quality monitoring locations, including those locations within existing AQMAs. The results of the modelling indicate that all monitoring locations are expected to have concentrations below 40 $\mu g/m^3$ which further demonstrates that the package of measures will improve local air quality including within existing AQMAs.

The ruling of the Client Earth 2 set out three tests that Clean Air Plans (the Feasibility Study) must meet in order that they are seen to comply with Article 23 of the EU Directive. The third test states that the plans must demonstrate that compliance with the limit values is not just possible, **but likely.** Probability analysis undertaken, indicates that modelled levels of 31.9 $\mu g/m^3$ gives a greater than **90%** probability that compliance with the limit value will **be achieved,** when the measures are implemented.

A significant outcome of the analysis is that the package of measures shows that a real reduction in emission occur, with significant health benefits.

In terms of the air quality benefits the preferred option significantly outweighs the air quality benefits of the CAZ option. Further the measures have been shown to reduce emissions of other pollutants especially particulate matter pollution ($PM_{2.5}$), whereas for the CAZ option this shows $PM_{2.5}$ emissions increasing. The air quality assessment shows that the CAZ measure just moves the pollution from within the CAZ area to outside, potentially negating any health benefits that are realised from achieving compliance on Castle Street

The Distributional Impact Analysis demonstrates that the most deprived part of the population as well as the population with the highest proportion of children would see the greatest air quality improvements from the preferred option of the package of measures, and that the measures do not have a direct household cost.

Owing to the City Centre Schemes, there is a monetised time disbenefit that has been calculated as part of the economic appraisal, which has a significant impact on the CBA of the preferred option. However as detailed previously, this time disbenefit is likely to be a significant over estimation owing to the limitations of the existing transportation model and assessment undertaken to date. The specific reasons for this assumption are:

- the results are based on single year (which has then been extrapolated over the 10 year CBA assessment period);

- It does not take in to account the demand response (assuming that people only re-route, **rather than change modes of transport**);
- It does not take account of congestion improvements expected at the culmination of the roadworks.
- It does not take into account the major projects and interventions committed to or identified by the forthcoming new Transport Vision that could be implemented over the assessment period. These could potentially offset the increased journey times arising from the proposed measures

It must be noted that this disbenefit is not a direct 'pocket' cost to businesses or individuals and the distributional analysis indicates that for 75% of journey this increase is between 0-5 minutes only.

In light of the above the Council still considers the package of measures as its preferred option to achieve compliance.

7.2 Next Steps

This report will be reviewed and assessed by the Welsh Government's Expert Review Panel, prior to final approval of the preferred option being provided from Welsh Government.

Upon approval and confirmation of appropriate funding from Welsh Government, the Council will commence the implementation of the preferred option in line with the Implementation Plan detailed in the Management Case.

Appendix A - Air Quality Modelling Results and Methodology Reports

Appendix B - Transport Modelling Technical Approach

Appendix C - Clean Air Strategy

Appendix D - Project Risk Register

Appendix E – Consultation Response Report

Appendix F - Economic Appraisal Methodology Report

Appendix G - Distributional Analysis Results Methodology Report

Cardiff Clean Air Feasibility Study - Air Quality Modelling Results Report

Report for Cardiff City Council

ED 11182 | Issue Number 2 | Date 31/05/2019

Customer:

Cardiff City Council

Customer reference:

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Date:

31 May 2019

Ricardo Energy & Environment reference:

Ref: ED11182- Issue Number 2

Table of contents

1 Introduction and outline scope of modelling

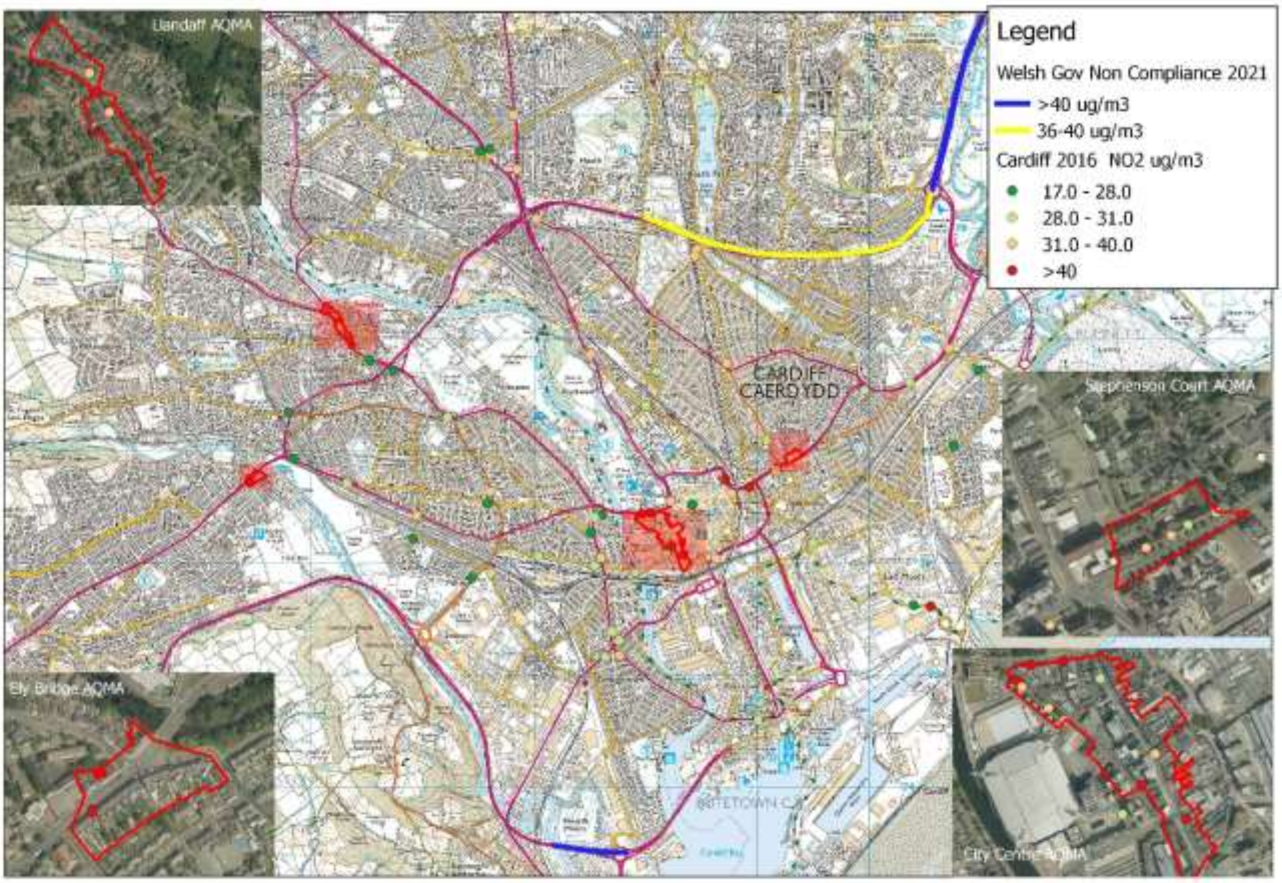
This report sets out the Air Quality modelling results that informed a feasibility study for Cardiff City Council on measures to achieve compliance with nitrogen dioxide (NO_2) limit values.

1.1 Background

Cardiff, like many cities across the UK, continues to have areas of poor air quality and has been identified as one of the cities where some areas will continue to exceed the nitrogen dioxide (NO_2) limit values beyond 2020. The national air quality plan has identified 2 specific roads that are likely to continue to exceed the Air Quality Directive Limit values: the A48 coming into the city from the North East and the A4232 to the South West of the city centre.

In addition, the city has declared 4 Air Quality Management Areas (AQMAs) in relation to NO_2 exceedances. There are two in the city centre: the city centre AQMA and the Stephenson Court AQMA. The other AQMAs are the Llandaff AQMA to the North West of the centre and the Ely Bridge AQMA to the West of the centre. A map of the exceedance roads identified in the national assessment and the AQMAs is shown in Figure 1.

Figure 1: AQMAs and compliance roads in Cardiff



Source apportionment assessment carried out by the Council has identified that diesel cars and vans are the main contributor to NO_2 concentrations in both the AQMAs and the national exceedance roads. The exception to this is the city centre AQMA which has a large contribution from bus and coach traffic.

Cardiff is the largest city in Wales and a major base of employment in South Wales. As such, any action to improve air quality in Cardiff will not only benefit residents of the City but also people commuting into the capital from the wider region. In addition any action to address the health impacts of air pollution in Cardiff can play a critical role in supporting other priorities such as active travel, health inequalities, integrated care, sustainability, growth and regeneration, localism and community engagement.

Because of these air quality issues and the potential for wider benefits across Cardiff and South Wales, the Council has been directed by the Welsh Government to carry out a Clean Air Zone feasibility study to develop a plan that will achieve compliance with the Air Quality Directive in the shortest possible time. The City has already been developing a Clean Air Strategy (CAS) setting out key measures to improve air quality in the city. This strategy provides an initial starting point for a formal plan, along with the consideration of potential charging based access restrictions, to ensure compliance with the limit values in the shortest possible time.

1.2 Outline scheme options

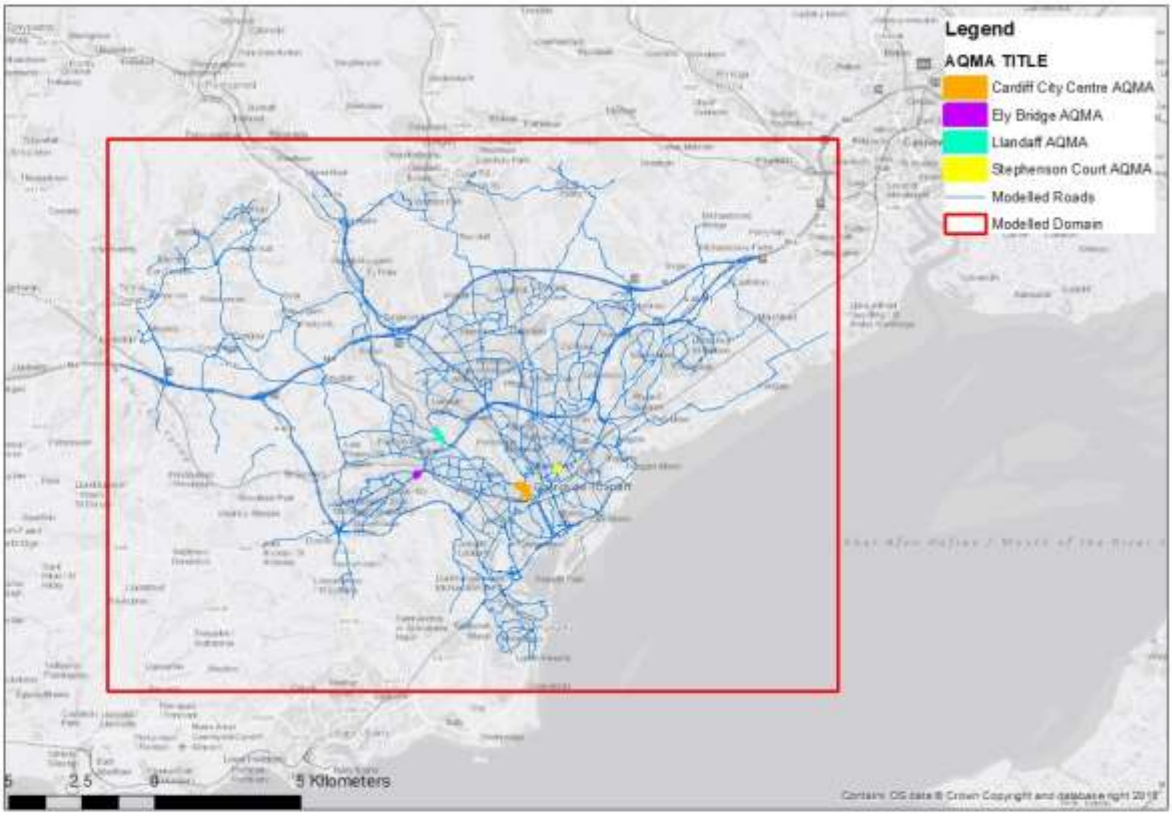
In total, seven future scenarios for 2021 have been modelled under this work, as follows:

- Business-as-usual (BAU). For more details of this scenario, see Section 2.1.
- Three Clean Air Strategy and Action Plan (CASAP) scenarios. These three scenarios are based on measures developed in the draft Clean Air Strategy and Action Plan and the scenarios are cumulative. For example, CASAP 3 included the measures from CASAP 1 and CASAP 2. For more details of these scenarios, see Section 2.2.
- Two Clean Air Zone scenarios. These looked at two different options for a charging zone in Cardiff improve air quality. For more details of these scenarios, see Section 2.3.
- A final ‘preferred’ CASAP scenario. This incorporated measures from CASAP 1, 2 and 3, with these measures being slightly amended in some cases. For more details of this scenario, see Section 2.2.4.

1.3 Model domain

A detailed modelling exercise was carried out to provide an initial estimate of NO_2 concentrations across Cardiff for a base year of 2015 and a target year of 2021. The area modelled extended to 1km beyond the city’s boundary and covered the PCM links of concern in the national modelling and local AQMAs. The PCM model is Defra’s and the devolved administrations national compliance model used to report the UK’s air quality status to the European Commission. This model domain is illustrated in Figure 2.

Figure 2 Air quality modelling domain



There are three main components of the model:

- *The South East Wales Traffic Model (SEWTM)* – this is a strategic traffic model developed for the Welsh Government that covers the Cardiff area. This model provided traffic data in terms of traffic flows (AADT[1]) and speeds. The traffic flows are provided for cars, LGVs, HGVs and buses. In addition, for the 2021 model year the vehicle categories have been split further into compliant and non-compliant vehicles. Compliant vehicles are those that meet the CAZ emission standards set out in the UK Government's Clean Air Zone Framework and non-compliant vehicles are those that don't[2]. It should be noted that for the purposes of the traffic modelling, taxis are included within the car flows and coaches are not included in the modelling at all (in line with standard practice).

- *Local ANPR fleet data* – a set of ANPR data was collected in May 2018. This data comprised of seven main sites covering each of the AQMAs in the city and the two stretches of road that the PCM modelling showed would be exceeding NO_2 thresholds in 2021 (A48 and A4232). The data was collected over a 1-week period and provided a detailed breakdown of the fleet composition in these areas. These data were used to provide fleet descriptions for seven distinct zones in the model domain, as illustrated in Figure 3, detailing:
  - The split of compliant and non-compliant vehicles, that would feed back into the transport model;
  - The breakdown of vehicles by fuel type and Euro standard;
  - The split of vehicles between rigid and artic HGVs;
  - The proportion of car traffic which was estimated to be taxis.

[1] Annual average daily traffic
[2] For details of the standards, see Annex A at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/612592/clean-air-zone-framework.pdf. For example, this shows that for petrol cars and diesel cars, compliant cars are those that are Euro 4 and above or Euro 6 and above respectively.

- *Ricardo's emissions and dispersion modelling suite RapidAir* – the emission component of this takes the traffic activity data and fleet data and provides emission results for each 'link'[3] in the traffic model. The dispersion component of the modelling suite then takes these emissions and generates a 1m x 1m grid of NOx concentrations. This is combined with the national background maps to provide NO_2 concentration results. The model is calibrated against monitoring data in the 2015 base year.

Figure 3 Fleet Zones used in the air quality model

1.4 Modelling years

As mentioned above, estimates of NO_2 concentrations across the modelling domain were made for a base year of 2015 and a target year of 2021. Concentrations for intermediate years were derived from interpolation.

1.5 Background modelling

The primary cause of air pollution problems in Cardiff is related to traffic activity and the impact of the any measures will target this traffic activity. As such the focus of the modelling is the transport emissions. Background pollutant concentrations can be taken from Defra's background maps which includes contributions from the majority of potential emissions sources e.g. other road traffic, industrial combustion and domestic emissions. With increasing distance from these emission sources Defra's background maps represent these emission sources relatively well. However, within close proximity to these emission sources Defra's Background maps can under-represent emissions.

[3] A 'link' in this context being a stretch of road where air pollution is estimated within the PCM model.

To ensure a realistic representation of background pollutant concentrations, Part A(2) and B emissions to air processes permitted through the environmental permitting regime were reviewed. The outcome of this review is that the distance of industrial sources is such that they will be satisfactorily represented within Defra's background maps. Further information is provided in section 4.4 of the air quality methodology report.

Defra's background maps are based upon the same methodology as the PCM model[4]. These are based upon simplifications of emission sources from various sectors such as industry, the meteorological conditions and dispersion environment which cause pollutant concentrations. As Defra's guidance note on background concentrations states, these are estimates, to gauge how accurately these estimates represent background concentrations a comparison can be made against background monitoring locations. There is one background continuous analysers and two diffusion tube locations which can be compared against the estimated background concentrations, this comparison can be seen in Table 1. This shows that Defra's background estimates are actually higher than measured concentrations and use of these are slightly conservative.

Table 1 Comparison of Defra's modelled background concentration with measured

ID	Site Type	2015 Measured NO2 (µg/m3)	2015 Measured NO2 Data Capture %	2015 Defra Background modelled NO2 (µg/m3)	% difference between measured and monitoring
CA_1	Urban Centre	27	80	27.4	1%
169	Urban Background	16.3	100	18.4	13%
160	Urban Centre	27	92	27.4	1%

[4] https://laqm.defra.gov.uk/documents/2015-based-background-maps-user-guide-v1.0.pdf

2 Options assessed and modelling assumptions

2.1 Baseline scenario

The assessment year for all future scenarios is 2021. The basic projections used for the future year baseline scenario are:

- **AADT flows for future baseline year** were provided from the SEWTM. Further information on how these traffic flows were derived and how local growth in traffic is calculated is presented in 'Transport Modelling Methodology Report'[5]. This will account for the effect of committed developments upon traffic in and around Cardiff.
- **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 HGVs into artic and rigid, and cars into private hire and hackneys 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 projection 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.
- **Compliance split for future fleet** All future scenarios, including the baseline 2021 scenario, have a separate fleet mix for compliant and non-compliant vehicles. The projected 2021 Euro standards for different vehicle types were split into categories of compliant and non-compliant. The Euro standards which fit into these two categories are listed within Table 2.

Table 2 vehicle type Euro standards categorised as compliant/non-compliant

Compliant				Non-Compliant			
Car	Vans	HGV – Rigid/Artic	Bus	Car	Vans	HGV – Rigid/Artic	Bus
Euro 4-6	Euro 4-6	Euro VI	Euro VI	Euro-3 and older	Euro-3 and older	Euro-V and older	Euro-V and older

Ricardo provided the 2015 and 2021 compliance split at each ANPR location to enable the traffic modellers to split their highway matrices (vehicle categories) into compliant/non-compliant vehicle types. As a result, traffic model outputs provided contained traffic flow (AADT) accompanied with a compliant/non-compliant factor for all modelled vehicles. This was used to apportion traffic flows to the compliant/non-compliant fleet mixes.

- **Future year scenarios average vehicle speed data:** The same volume-weighted average speed approach used for the base year, and described in section 4.3.1 of the methodology report, was adopted for the future baseline scenarios. The same speeds were applied to both compliant and non-compliant vehicles.
- **Projected vehicle NOx emission rates** will be calculated using the latest COPERT v5 NOx emission functions applied to AADT, speed, fleet and vehicle age composition for each future baseline year being modelled.

[5] 367590 Air Quality Transport Modelling Technical Note CASAP CAZ

2.2 CASAP scenarios

2.2.1 CASAP 1

The CASAP 1 scenario included measures from the draft Clean Air Strategy and Action plan (a) for which a funding application has been made but the funding had not yet (at the time of modelling) been confirmed, or (b) which can be implemented with minimal cost to the Council.

The components of the scenario are outlined in Table 3 below.

Table 3: modelling assumptions for CASAP 1

Measure	Modelling assumptions
Active travel package	Measures rolled out in two areas of the city which assume a 3,5% reduction in car driver mode share and applied in the transport model.
Cycling programme to end of 2020	Focused on the Heath to City centre corridor and assumed a 3.5% reduction in car driver share, as above, and applied in the transport model.
50mph limit on A4232	Reduction from the national speed limit to 50 mph and applied in the transport model.
ULEB application for 36 electric buses	The 36 buses were allocated to routes 27, 49/50, 44/45, with the related bus AADT removed as these are now zero emission. The remaining bus fleet is then adjusted to reflect the removal of 36 older Euro3 vehicles.
Taxi licensing requiring a 10 year age limit and all new vehicles Euro 6 from 2019	Taxi fleet adjusted to remove all vehicles over 10 years old and replace these by new Euro 6 vehicles

2.2.2 CASAP 2

The CASAP 2 scenario included measures which the Council would like to introduce but where no funding is in place or an application has yet to be made for funding.

The components of the scenario are outlined in Table 4 below.

Table 4: modelling assumptions for CASAP 2

Measure	Modelling assumptions
Includes the measures from CASAP 1 plus the following	
City Centre West Transport Improvement Scheme	Through movements prevented from using Westgate Street and applied in the transport model.

Part of East side city centre scheme (Station Terrace)	Through movement prevented on Churchill Way, except for buses, and applied in transport model
A48 package - Includes gating of traffic via signals, expansion of bus lanes on A48	Vehicle trip passing the P&R location and destined for the city centre were identified. It was then assumed that 3% of these trips would move to the improved P&R service. This change was then applied in the transport model.
Accelerated delivery of P&R in north west of Cardiff and expansion of P&R on A48	As above the number of trips that could potentially make use of this service were identified and then based on the capacity of the P&R site 150 vehicles were removed from the 'in scope' trips.
Parking charges and controls, affecting vehicles with non-compliant engines	It was assumed that the parking charges and controls would take the form of an additional £5 per day levy for Council-owned/managed on-street and off-street spaces in Cardiff city centre, applicable only to vehicles not compliant with the CAZ standards (i.e. Euro 6 diesel, Euro 4 petrol).

2.2.3 CASAP 3

As outlined in Section 3 on the modelling results, the results of baseline modelling showed there to be NO_2 exceedances in different areas to those shown by the national PCM model. In particular, the baseline results showed that concentrations were higher in the city centre than previously shown in the PCM model, and with levels close to the limit value on the A470. Hence a further modelling scenario was developed – labelled CASAP 3 – to address these road links, focusing specifically on the city centre and the A470. Because all the CASAP scenarios are cumulative, CASAP 3 includes the measures outlined in CASAP 1 and 2.

The additional measures selected for CASAP 3 were as follows:

Table 5: modelling assumptions for CASAP 3

Measure	Modelling assumptions
Includes the measures from CASAP 1 & 2 plus the following	
A470 additional southbound traffic lane	Additional general traffic lane (Nantgarw to Tongwynlais) created by narrowing other lanes.
Nantgarw bus P&R	New bus-based Park and Ride close to A470/A468/A4054 junction. Access to P&R from A4054 near Nantgarw, with a new bridge across the river. Note that this is the same location as a potential future rail-based P&R, but operating as bus-based initially.
CBTF retro-fit programme	To convert remaining buses to Euro 6 to complement the electric buses in CASAP 1.

2.2.4 Preferred CASAP scenario

Following the analysis of the CASAP 1, 2 and 3 scenarios (see section 4.1), a preferred scenario was developed. This consisted of a number of individual measures from the three CASAP scenarios, some of which were slightly amended based on discussions with the project team and Cabinet.

The individual measures included in the preferred CASAP scenario, and a summary of the modelling assumptions used to represent them, are shown in Table 6 below.

Table 6: Preferred CASAP scenario modelling assumptions

Measure	Modelling assumptions
Active travel package	20mph zones and cycle scheme CS1 (Heath to City centre corridor) measures rolled out in two areas of the city, which assume a 3.5% reduction in car driver mode share and applied in the transport model.
ULEB application for 36 electric buses	The 36 zero emission buses were allocated to routes 27, 49/50, 44/45, with the related bus AADT removed as these are now zero emission. The remaining bus fleet is then adjusted to reflect the removal of 36 older Euro3 vehicles.
CBTF retro-fit programme	Assumed 80% uptake of retrofit of remaining non-Euro 6 buses to Euro 6, to complement the electric buses measure above.
Taxi licensing	Sets a 10 year age limit and all renewals to be Euro 6 from 2019. Plus a grant scheme for taxi drivers, when renewing to Euro 6, to buy plugin hybrids or fully electric vehicles. Taxi fleet adjusted to remove all vehicles over 10 years old and replace these by new Euro 6 vehicles. Assumed that this results in a 15.8% shift from non-compliant to compliant private hire vehicles (of which, 7% assumed to upgrade to an electric vehicle), and a 45.5% shift for hackney carriages (of which, 4% assumed to upgrade to an electric vehicle).
City Centre transport schemes, including City Centre West Transport Improvement Scheme, Part of East side city centre scheme (Station Terrace) and the Castle Street scheme.	City Centre West Transport Improvement Scheme modelled through movements prevented from using Westgate Street and applied in the transport model. East side city centre scheme modelled through movement prevented on Churchill Way, except for buses, and applied in transport model. Castle street scheme modelled with removal of vehicle lane and replacement with a cycle lane. Westgate and East side measures now assume exceptions for taxis (not included in CASAP 1-3 modelling)

2.3 The CAZ scenarios

The UK Government has published a Clean Air Zone (CAZ) framework for English local authorities that sets out some key criteria for CAZ charging schemes covering:

- *The legal basis* – which is the road user charging powers under the Transport Act 2000;
- *The emission standards* - below which vehicles would be charged:
    - Euro VI for heavy duty vehicles, i.e. trucks and buses;
    - Euro 6 for light duty diesel vehicles (cars and vans);
    - Euro 4 for light duty petrol vehicles.
- *Charging scheme class* – that defines which vehicle types would be subject to the scheme:
    - Class A – buses and taxis
    - Class B – buses, taxis and HGVs
    - Class C – buses, taxis, HGVs and LGVs
    - Class D - buses, taxis, HGVs, LGVs and cars

The framework also states that a scheme should operate for 24 hours, 7 days a week. However, the level of charge and any exemptions is left up to the local authority to determine.

The Welsh Government has suggested that Welsh cities such as Cardiff do not necessarily need to stick rigidly to the English framework, though would be expected to adopt the same emission standards. There has even been discussion as to whether Welsh cities should adopt the legal basis proposed in England, based on charging regulations, or the Traffic Regulation Order basis being pursued in Scotland for Scotland's Low Emission Zones.

An initial consideration of potential scheme options was carried out in Cardiff for short listing and assessment in the final plan, to complement the Clean Air Strategy measures if necessary. This initial consideration has taken the English framework as the starting point and assumed that road user charging legislation would be the legal basis for the scheme. This section outlines potential boundaries and vehicles types (or classes) that the scheme could cover.

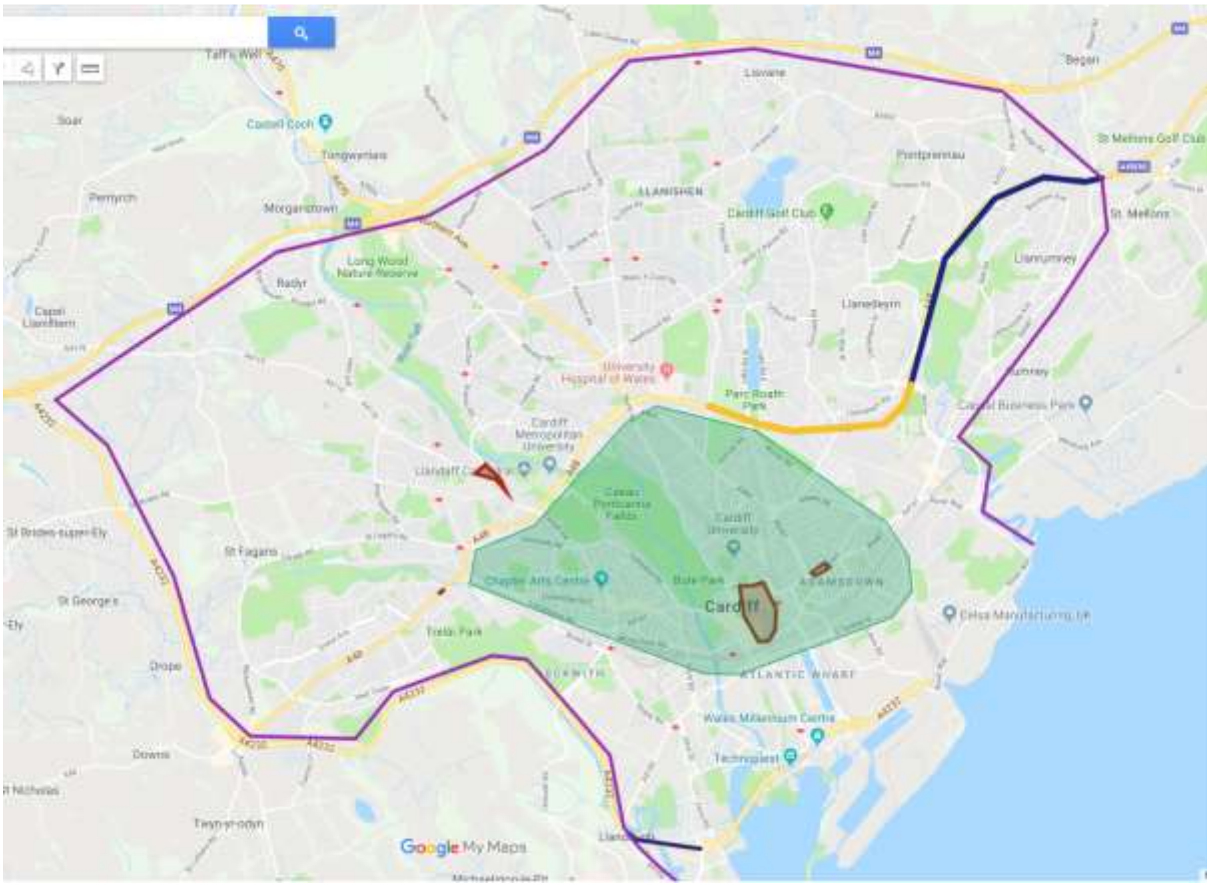
2.3.1 Charging scheme boundaries

Like most cities there are some clear natural boundaries that can be easily understood by drivers affected by the scheme and hence form the natural choices for boundaries for the scheme options. For Cardiff these boundaries are:

1. *City wide boundary* – covering the area within the M4 to the North and the A4232 to the West. This area covers all the AQMAs in the city and the major road links of concern under the PCM modelling. This is shown by the purple line in Figure 4 below.
2. *Central boundary* – covering the area within the A48 which is the main through route in the city. This covers the AQMAs in the city centre and at Stephenson Court, as well as the links showing as exceeding in the local air quality modelling, but does not cover the AQMAs at Ely Bridge and Llandaff, or the PCM roads of concern in the national modelling (although influencing traffic that is accessing this area will have a wider knock on effect to areas beyond this boundary). This boundary is shown in the light green hatched area in Figure 4 below.
3. *A doughnut scheme* – where one or more vehicle types are targeted for the city wide boundary, with additional vehicles types targeted in the central area.

Each of these boundaries also provides a diversion route for vehicles wishing to pass through the area that do not meet the emission standards – the M4 for the city wide boundary and the A48 for the central boundary.

Figure 4: Potential scheme boundaries



2.3.2 Vehicle types covered

Source apportionment analysis (see Section 0) indicates that whilst HGVs and diesel cars are likely to contribute the largest proportions of emissions, all vehicle types are contributing to the problem, but this will vary from location to location. Therefore, for this work, all vehicles types were kept under consideration for the charging scheme. However, some vehicles types may be tackled more effectively through other mechanisms, in particular:

- *Buses* – can be subject to a traffic condition in relation to emissions performance as has been done in Oxford. This can be combined with partnership working and grant funding to provide both a stick and a carrot to get buses up to a Euro VI or better standard (such as electric).
- *Taxis* – can be affected by setting standards within the licencing regime, an option already being implemented through the Clean Air Strategy. This is a group that will often likely have significant financial constraints to upgrading their vehicles and so combining licensing with grant schemes and supporting infrastructure for electric vehicles can be effective.

Given these considerations the focus was initially on HGVs, LGVs and cars, or Classes B, C and D using the national framework terminology (though these classes would also include buses and taxis which could be treated separately as noted above). Combining these vehicle types with the potential boundaries discussed above gives rise to 9 potential scheme options as illustrated in Table 7 below. Comprising of:

- 3 city wide options – one for each of the vehicles classes which would be cumulative as per the CAZ framework;
- 3 central zone options – as per the city wide scheme but just covering the central area;
- 3 doughnut options – covering HGVs only for the city wide boundary and additionally covering LGV or LGV and cars in the central boundary; or HGVs and LGV city wide, with cars also included in the central boundary.

Table 7: combinations of zone boundary and vehicle type

Vehicle types	City wide	Central zone	Doughnut	
			City wide	Central zone
HGVs	1	4	7/8	7= LGVs 8 = LGV and cars
HGV, LGVs	2	5	9	Cars
HGVs, LGV, Cars	3	6	-	-

2.3.3 Wider considerations

There are also a number of other considerations in terms of scheme design that have been discussed and will need to be explored further in any final options going forward. These considerations are designed to make any scheme as practical and effective as possible whist not having a disproportionate impact on specific groups. They cover:

- *Exemptions* – for example buses and taxis for the reasons considered above but also groups such as disabled, emergency vehicles and specialist vehicles.
- *Time of day* – the national framework suggests it should be 24/7 but if flexibility is available to Welsh cities consideration could be given to applying charges only at peak times or during week days.
- *Charging levels* – the London ULEZ scheme which is based on the same principles as the national framework sets a charge of £100 for heavy vehicles (trucks and buses) and £12.50 for light vehicles (cars and vans). Variations to this that have been discussed are:
  - Lower charges for both vehicle types;
  - Phasing in charges so they increase over (for example) 3 years;
  - Having a low charge for all vehicles, with a higher charge for non-compliant vehicles so combining standard road user charging with environmental charging;
  - Lower rates for some groups in a similar fashion to exemptions (see first bullet point above).

2.3.4 Initial conclusions

The initial results from the local modelling indicated that the areas of concern all lie within the central charging boundary being considered. As such it was felt sensible to focus scheme options on this boundary, but accounting for any diversionary impacts on areas beyond this.

Additionally, the source apportion indicates that the key contributors to the exceedance areas are diesel cars, followed by HGVs. As such it suggests that schemes covering HGVs and/or cars should be the target of any charging option in the central area. This provides two potential options that were taken further for exploration in the final plan.

As set out in Section 3, the baseline air quality modelling results showed that all the links that were expected to be exceeding NO_2 limit values in 2021 were in the central charging boundary under consideration. Furthermore, source apportionment showed that the key contributors to the exceedance areas are diesel cars, followed by HGVs and then LGVs. An internal workshop was held with Cardiff Council Officers and members to consider charging scheme options. The primary option generated by this workshop was the central CAZ targeting diesel cars which are the principal source of NOx emissions. Further internal discussions then identified a second option focused on freight vehicles, as an alternative to a scheme targeting private cars.

Hence, the two CAZ options modelled were:

- CAZ 1 - A city centre CAZ for private cars only, based on a £10 charge for non-compliant vehicles;
- CAZ 2 - A city centre CAZ for heavy goods vehicles (HGVs) and light goods vehicles (LGVs), based on a £50 charge for HGVs and £10 charge for LGVs.

2.3.5 CAZ 1

This scenario was a city centre CAZ for private cars only, based on a £10 charge for non-compliant vehicles. The components of the CAZ 1 scenario and a summary of the modelling assumptions used are shown in Table 8 below.

Table 8: modelling assumptions for CAZ 1

Measure	Modelling assumptions
City centre charging CAZ for private cars (CAZ 1)	Assumes £10 charge for private cars. Defra's joint air quality unit (JAQU) has developed behavioural responses to charges on private car. These have been adopted by the transport and air quality modelling used in this project. See section 6 within the transport report for the traffic modelling methodology[6]. In summary, transport modellers applied linear interpolation to JAQU's £12.50 behavioural responses to establish responses to a £10 charge. As the transport modellers have provided the % split of compliant and non-compliant cars in response to CAZ, only an update to the fleet mix within the CAZ was necessary. To prevent a step change in concentrations occurring with the implementation of a separate fleet mix for compliant/non-compliant cars, a compliant/non-compliant fleet mix was used in the future baseline (2021). Consequently, for CAZ 1 the change in number of compliant cars was achieved by applying the updated CAZ 1 compliant/non-compliant % split to traffic flows (AADT). There are no JAQU upgrade assumptions for non-compliant vehicles to a specific euro standard or fuel type. There is only a % upgrade assumption to compliant vehicles and those which will switch from non-compliant diesel to compliant petrol. As the traffic modellers have already included the % upgrade within their traffic modelling, the only adjustment made to the fleet mix used for pollutant emission calculations is the split between petrol and diesel cars. Consistency was maintained between air quality modelling and transport modelling, and linear interpolation of JAQU behavioural responses was applied to the % upgrade from diesel to petrol. This adjusts JAQU's £12.50 % upgrade from 64.3 to 51.44%.

[6] 367590 Air Quality Transport Modelling Technical Note CASAP CAZ.pdf

2.3.6 CAZ 2

This scenario was a city centre CAZ for heavy goods vehicles (HGVs) and light goods vehicles (LGVs), based on a £50 charge for HGVs and £10 charge for LGVs. The components of the CAZ 1 scenario and a summary of the modelling assumptions used are shown in Table 9 below.

Table 9: modelling assumptions for CAZ 2

Measure	Modelling assumptions
City centre charging CAZ for light goods and heavy goods vehicles (CAZ 1)	Assumes £10 charge for LGVs and £50 for HGVs. JAQU has developed behavioural responses for LGV and HGV car charges. These have been adopted by transport and air quality modelling. The traffic modelling methodology can be found within the transport report[7]. In summary, the transport modellers applied linear interpolation to JAQU's £12.50 (LGV) and £100 (HGV) behavioural responses. This establishes responses to a £10 and £50 charge for LGVs and HGVs, respectively. As the transport modellers have provided the % split of compliant and non-compliant cars for responses to CAZ, only an update to the fleet mix assumed within the CAZ is necessary. To prevent a step change in concentrations occurring with the implementation of a separate fleet mix for compliant/non-compliant LGVs and HGVs, a compliant/non-compliant fleet mix was used in the future baseline (2021). Consequently, for CAZ 2 the change in number of compliant LGVs/HGVs was achieved by applying the updated CAZ 2 compliant/non-compliant % split to traffic flows (AADT). There are no JAQU upgrade assumptions for non-compliant vehicles to a specific euro standard or fuel type. There is only a % upgrade assumption to compliant vehicles and those which will switch from diesel to petrol. As the traffic modellers have already included the % upgrade within their traffic modelling, the only adjustment made to the fleet mix used for pollutant emission calculations is the split between petrol and diesel LGVs. No fuel type switch for HGVs was calculated as diesel is the only fuel type for HGVs. Consistency was maintained between the air quality modelling and the transport modelling and linear interpolation of JAQU behavioural responses was applied to the % upgrade from diesel to petrol. This adjusts JAQU's £12.50 % upgrade from 75 to 60%.

[7] 367590 Air Quality Transport Modelling Technical Note CASAP CAZ.pdf

3 Model results for 2015 base year and 2020 'BAU' baseline

3.1 Comparison with PCM

For comparison with PCM model results, annual mean NO_2 concentrations at the roadside locations assessed in the national compliance PCM model have been extracted from the RapidAir dispersion model results; the results have been presented in both tabular form and graphically as maps of the study area.

Roadside receptor locations in the PCM model are at a distance of 4m from the kerb and at 2m height. To represent this in our city scale modelling, a subset of the OS Mastermap GIS dataset provided spatially accurate polygons representing the road carriageway. Receptor locations were then placed at 10m intervals along relevant road links using a 4m buffer around the carriageway polygons. Each PCM link has a unique Census ID number and a grid reference assigned which is typically the co-ordinates describing the location of the DfT traffic count points on each link; this location may not however be where the highest roadside concentrations are occurring along the entire link length when using a more detailed local scale modelling method with observed average vehicle speeds on shorter road sections. The PCM links within our model domain range in length from approximately 120m to 3.25km; we have therefore reported the highest of the modelled concentrations for each link, from the city scale model receptors spaced at 10m intervals, 4m from the carriageway.

A full list of tabulated results comparing the PCM baseline results with the local modelled results from 2015 to 2021 is shown in Table 10. This shows estimated NO_2 concentration for each PCM link and is colour coded as green for less than 35µgm^{-3}, amber between 35µgm^{-3} and 40 µgm^{-3} and red for greater than 40µgm^{-3} (the compliance threshold[8]). For the local model only the baseline 2015 and future year 2021 results have been directly modelled, the intervening years have simply been interpolated between these two results.

Mapped results are shown in Figure 5 to Figure 8. These show two types of maps; one with the PCM links colour coded with the local results in the same way as the tabulated results (i.e. a whole link is colour coded to match the highest concentration along that link) and a second showing point locations of any local modelled receptors along the PCM links greater than 35 µgm^{-3}. It should be noted that the compliance limit is 40µgm^{-3}, but is formally defined as a whole number and so only results equal or greater than 40.5µgm^{-3} are considered non-compliant, and are colour coded as such in both the table and maps.

Looking first at the local model results overall, they show a somewhat different pattern to the PCM results. A difference is to be expected as the local and PCM modelling are done in different ways; for example road gradients and street canyons[9] are considered in the local model and not in the PCM model, which would tend to lead to higher concentrations in the local model.

Focusing on areas of exceedance in 2021, the national PCM model showed exceedances on the A48 to the east of the city and the A4232 to the south west. The local model however suggests that both these locations would be comfortably within compliance. The differences between the PCM and local model will be explored further at these locations, but one possible reason is that the PCM model uses generic urban speeds for these links whereas the local model uses local speeds from the traffic

[8] The compliance limit is 40µgm^{-3}, but is formally defined as a whole number and so any result less than 40.5µgm^{-3} which rounds down to 40µgm^{-3} is considered compliant.
[9] A street canyon is where buildings create a canyon effect, concentrating air pollution levels in a specific area.

model. Since these are major dual carriageways the local speeds are likely to be higher than that seen in the PCM model and hence would generate lower emission rates.

The local model results are showing only one exceedance on PCM link ID30665 – the A4161 Castle Street. This exceedance is related to high traffic flows of some 32,000 vehicles a day, slow speeds of around 11mph and being located in a canyon.

Section 0 looks at the inherent uncertainty in modelling of this kind. This shows that whilst all efforts have been made to reduce the uncertainty, it is still possible that results could be higher or lower by around 5 µgm-3.

It should be noted that the NO_2 concentrations in the table and maps below only show the maximum concentrations for each PCM modelled road link. Certain roads in the modelling domain are not modelled in PCM and hence no concentrations are shown (e.g. M4).

Table 10 Comparison of PCM and local model NO_2 concentration results for 2015 through to 2021 (NO_2 in μgm^{-3})

CensusID	Road Name	LA Name	PCM Baseline 2015	PCM Baseline 2017	PCM Baseline 2018	PCM Baseline 2019	PCM Baseline 2020	PCM Baseline 2021	Local Baseline 2015	Local Baseline 2016	Local Baseline 2017	Local Baseline 2018	Local Baseline 2019	Local Baseline 2020	Local Baseline 2021
30660	A4119	Cardiff City Council	22.4	21.3	20.5	19.8	18.9	17.9	37.1	36.0	34.9	33.9	32.8	31.8	30.7
10629	A4054	Cardiff City Council	19.1	18.1	17.4	16.7	15.8	15.0	25.3	24.3	23.4	22.4	21.4	20.5	19.5
50647	A4119	Cardiff City Council	29.9	28.7	27.7	26.7	25.4	24.0	34.4	32.7	31.0	29.4	27.7	26.0	24.4
10660	A4161	Cardiff City Council	40.3	38.7	37.4	36.2	34.5	32.7	34.9	33.4	32.0	30.5	29.1	27.6	26.2
522	A48	Cardiff City Council	27.9	26.8	25.8	24.8	23.7	22.3	32.9	31.6	30.4	29.2	27.9	26.7	25.4
30659	A4119	Cardiff City Council	27.2	26.2	25.2	24.3	23.1	21.8	23.8	23.0	22.2	21.3	20.5	19.6	18.8
77018	A470	Cardiff City Council	31.1	29.8	28.7	27.7	26.4	25.2	45.4	42.9	40.5	38.0	35.5	33.0	30.6
99955	A4160	Cardiff City Council	32.2	30.7	29.6	28.5	27.1	25.7	36.7	35.1	33.5	31.8	30.2	28.5	26.9
50660	A4161	Cardiff City Council	43.7	41.4	39.6	37.9	35.9	33.8	42.2	40.3	38.4	36.5	34.6	32.7	30.8
70055	A4161	Cardiff City Council	37.5	35.9	34.5	33.1	31.5	29.7	43.9	41.7	39.4	37.1	34.9	32.6	30.4
99671	A469	Cardiff City Council	33.1	32.2	31.1	30.1	28.7	27.1	27.2	26.2	25.3	24.4	23.4	22.5	21.5
10659	A4160	Cardiff City Council	30.4	29.3	28.3	27.3	26.2	25.0	30.4	29.3	28.2	27.0	25.9	24.8	23.7
10655	A4119	Cardiff City Council	31.9	30.8	29.8	28.8	27.4	25.9	36.6	35.4	34.1	32.8	31.6	30.3	29.0
80898	A4232	Cardiff City Council	47.3	45.2	43.5	42.0	39.9	37.7	34.3	33.5	32.7	31.9	31.1	30.3	29.5
20527	A48	Cardiff City Council	48.8	46.9	45.2	43.6	41.5	39.1	40.0	38.4	36.9	35.3	33.7	32.2	30.6
40655	A4160	Cardiff City Council	28.2	27.1	26.1	25.1	24.0	22.7	24.2	23.4	22.6	21.7	20.9	20.1	19.3
50580	A469	Cardiff City Council	28.5	27.1	26.1	25.0	23.8	22.4	33.0	31.8	30.6	29.4	28.2	27.0	25.8
50657	A4161	Cardiff City Council	29.5	28.3	27.2	26.1	24.8	23.3	26.5	25.5	24.4	23.4	22.4	21.4	20.3
10661	A4161	Cardiff City Council	24.9	23.9	23.1	22.2	21.2	20.1	26.6	25.6	24.5	23.4	22.3	21.3	20.2
10527	A48	Cardiff City Council	31.9	30.8	29.6	28.6	27.2	25.7	29.4	28.3	27.2	26.1	24.9	23.8	22.7
40582	A469	Cardiff City Council	31.8	30.5	29.5	28.4	27.0	25.5	32.2	30.9	29.7	28.4	27.2	25.9	24.7
50651	A4119	Cardiff City Council	28.4	27.3	26.4	25.5	24.2	22.9	31.6	30.4	29.2	28.0	26.9	25.7	24.5
40656	A4161	Cardiff City Council	40.9	39.3	38.0	36.8	35.1	33.4	43.7	41.4	39.0	36.6	34.3	31.9	29.6
40549	A470	Cardiff City Council	40.8	39.1	37.7	36.3	34.5	32.5	38.1	36.3	34.6	32.8	31.1	29.3	27.6
50527	A48	Cardiff City Council	45.3	44.0	42.6	41.2	39.3	37.1	37.1	35.7	34.3	32.9	31.5	30.2	28.8
642	A4160	Cardiff City Council	38.3	37.1	36.1	35.0	33.6	32.1	40.0	38.1	36.2	34.4	32.5	30.7	28.8

80899	A4232	Cardiff City Council	43.1	41.1	39.5	38.1	36.3	34.3		32.1	31.3	30.6	29.8	29.0	28.3	27.5
99960	A4055	Cardiff City Council	34.9	33.7	32.6	31.5	30.0	28.4		31.4	30.4	29.5	28.5	27.5	26.5	25.5
50541	A470	Cardiff City Council	35.6	34.1	32.9	31.8	30.2	28.5		37.3	35.9	34.5	33.2	31.8	30.5	29.1
20548	A470	Cardiff City Council	31.3	29.8	28.6	27.5	26.1	24.6		41.3	39.4	37.6	35.7	33.8	31.9	30.0
50524	A48	Cardiff City Council	59.6	56.2	53.7	51.4	48.5	45.4		36.4	35.0	33.6	32.1	30.7	29.3	27.9
74101	A4232	Cardiff City Council	52.5	49.7	47.6	45.7	43.3	40.7		30.1	29.2	28.3	27.4	26.5	25.6	24.8
638	A4119	Cardiff City Council	27.5	26.1	25.0	24.0	22.8	21.6		28.8	27.7	26.6	25.6	24.5	23.4	22.3
30665	A4161	Cardiff City Council	41.2	39.0	37.3	35.7	33.9	31.9		55.7	53.2	50.8	48.4	46.0	43.5	41.1
73233	A4055	Cardiff City Council	35.8	34.6	33.4	32.3	30.8	29.1		31.6	30.4	29.3	28.1	26.9	25.7	24.5
99956	A4234	Cardiff City Council	44.6	43.1	41.8	40.5	38.7	36.8		38.2	36.2	34.2	32.3	30.3	28.3	26.3
78439	A4232	Cardiff City Council	33.6	32.0	30.7	29.5	28.1	26.4		21.7	21.0	20.3	19.6	18.9	18.2	17.5
70056	A4232	Cardiff City Council	42.2	38.2	36.0	34.0	32.0	29.9		35.3	34.2	33.2	32.1	31.0	30.0	28.9
73232	A4160	Cardiff City Council	26.9	25.6	24.6	23.6	22.5	21.2		21.0	20.6	20.1	19.6	19.1	18.6	18.1
80896	A470	Cardiff City Council	26.5	25.3	24.5	23.8	22.9	22.2		26.9	26.0	25.2	24.3	23.5	22.6	21.8
80726	A470	Cardiff City Council	35.4	32.6	30.9	29.1	27.2	25.3		34.8	33.2	31.6	30.0	28.4	26.8	25.2
78435	A4050	Cardiff City Council	30.2	28.5	27.2	26.0	24.6	23.1		32.5	31.2	30.0	28.7	27.5	26.3	25.0

Note: local results are colour coded as green for less than 35µgm^{-3}, amber between 35µgm^{-3} and 40 µgm^{-3} and red for greater the 40µgm^{-3} (the compliance threshold). Numbers are rounded to the nearest integer, hence any values less than 40.5 µgm^{-3} are not counted as exceedances.

Figure 5 PCM links colour coded with local model results for 2015

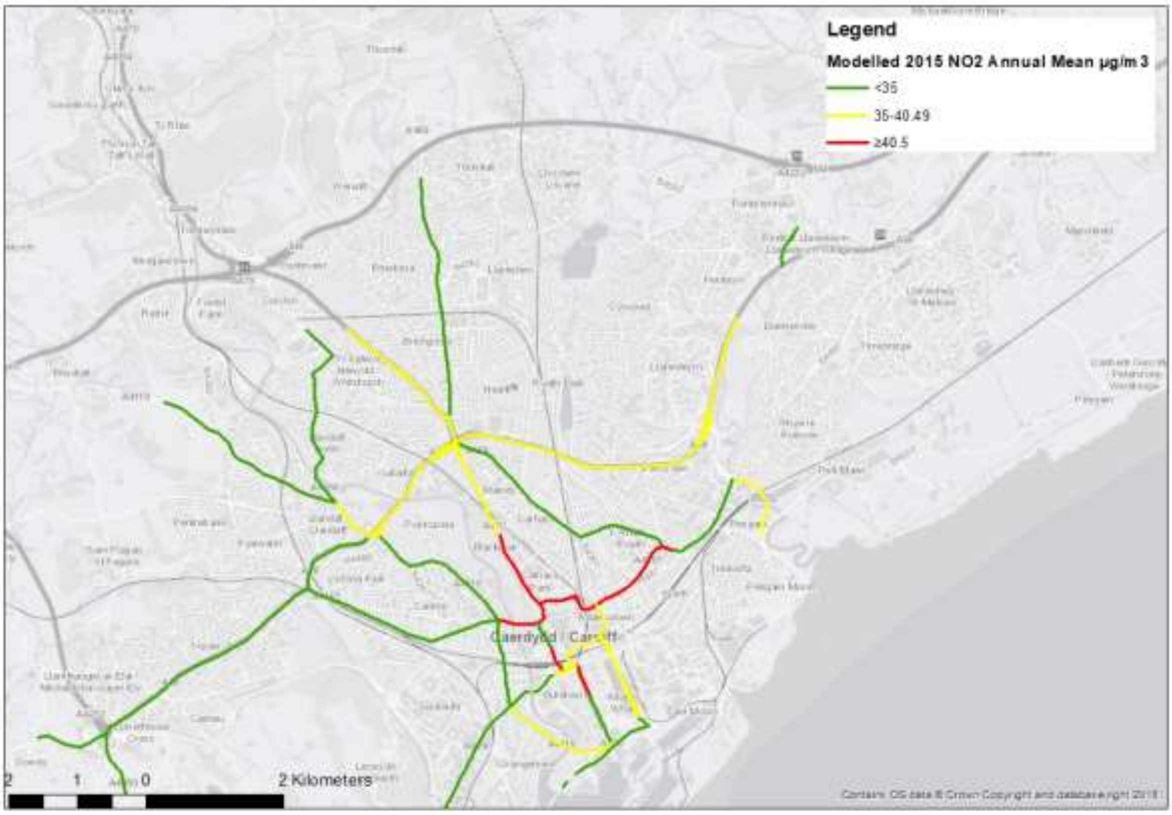


Figure 6 Sampled NO_2 results along the PCM links > 35 µgm^{-3} in 2015

Figure 7 PCM links colour coded with local model results for 2021

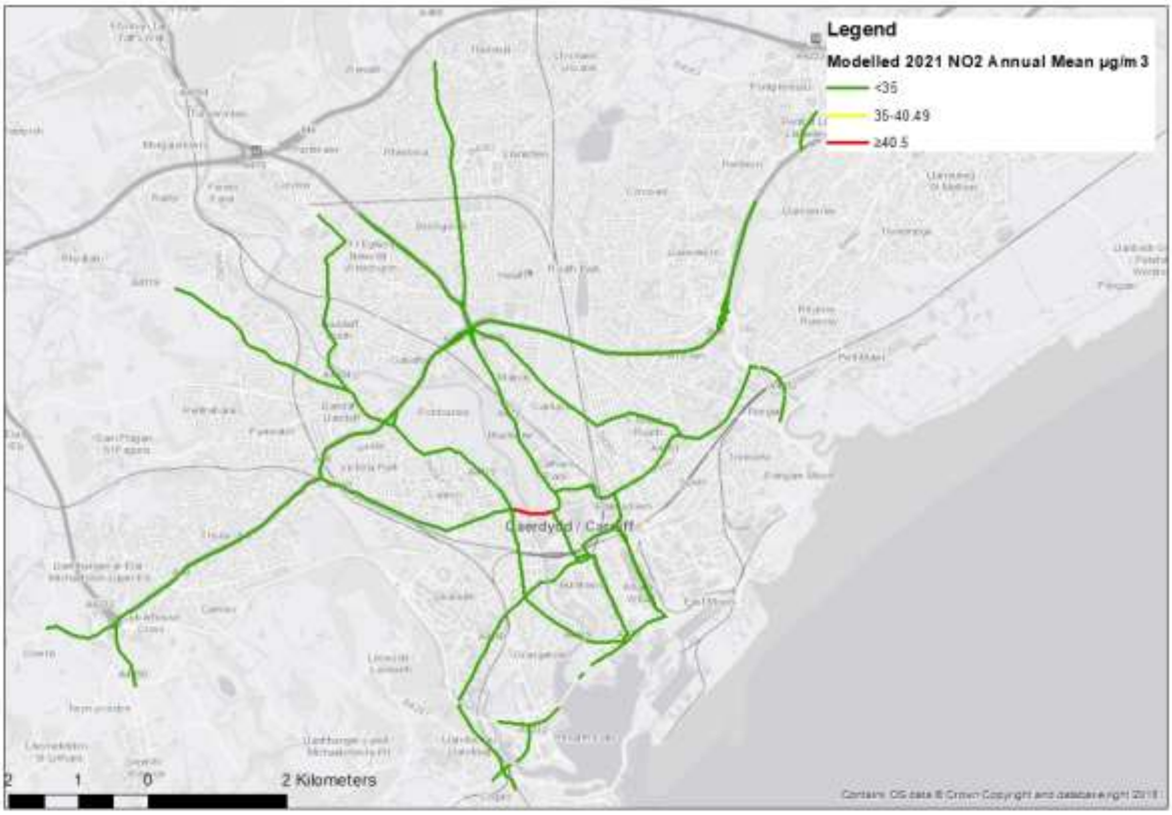
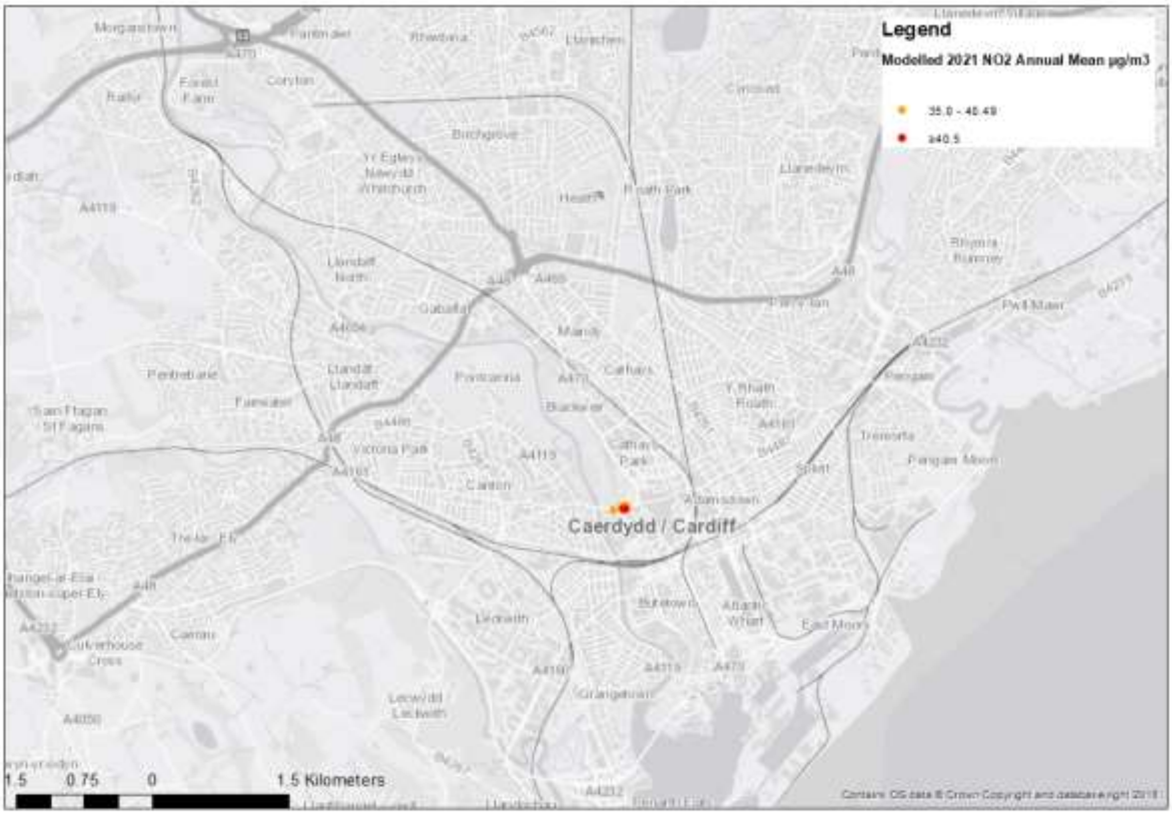


Figure 8 Sampled NO_2 results along the PCM links > 35 µgm^{-3} in 2021



3.2 Results for AQMAs and local exceedances

Modelled 2015 and 2021 NO_2 concentration results have been produced for the all the 2015 monitoring location used in model verification and additional sites added since 2105. The results are presented in Table 11 below and show:

- Measured data for 2015 and 2018;
- Modelled data for 2015 and 2018 using the global model adjustment factor;
- Modelled results for 2021 using a site-specific adjustment factor.

Some of the original 2015 monitoring locations used for model verification are no longer in operation and so do not have 2018 data. For new sites since 2015 only the 2018 measured data is shown and no site specific adjusted result can be produced. These sites are labelled as such in the table. These results provide an indication of whether compliance is predicted at monitoring locations in 2021. Based on the global adjustment factor two monitoring locations are predicted to exceed the 40 µg/m3 limit value in the 2021 baseline: site 186 on Castle street and site 176 at Castle Arcade which is in line with our PCM results reported above. When considering a site specific adjustment factor Castle Arcade site is now showing compliance as it was being over predicted with the global adjustment factor, and although a number of sites are showing increases against the globally adjusted results none is sufficient to cause any further exceedances.

Table 11: Predicted NO_2 annual mean concentrations at monitoring site locations in 2015 and 2021

Monitoring site name	Site ID	NO_2 annual mean ($\mu g.m^{-3}$)				
		Measured		Global Adjustment		Site Specific
		2015	2018[2]	2015	2021	2021
2015 sites used for model verification						
Ninian Park Road	16	27.9	26.4	18.8	14.2	20.4
Mitre Place	33	**46.9**	32.3	39.7	31.5	37.6
City Road	44	27.1	**N/A**	26.8	20.4	20.6
Mackintosh Place	45	32.1	**N/A**	30.4	23.4	24.6
Penarth Road	49	29.4	27.2	21.6	17.1	23.3
Birchgrove Village	56	29.6	22.8	22.0	17.1	23.1
Westgate Street	58	**48.3**	**46.4**	**41.7**	30.3	35.0
Stephenson Court	81	35.3	34.6	36.5	25.3	24.6
104 Birchgrove Road	82	23.8	**N/A**	23.4	18.0	18.3

497 Cowbridge Road West	85	22.4	**N/A**	19.5	15.2	17.4
19 Fairoak Road	86	34.9	32.9	24.5	19.0	27.0
Manor Way Junction	96	31.1	30.6	30.5	23.2	23.7
Newport Road (premises)	97	30.5	**N/A**	29.4	21.4	22.1
Western Avenue (premises)	98	25.4	25.0	22.9	18.2	20.2
Cardiff Road Llandaff	99	29.8	31.2	35.2	27.8	23.5
Cardiff AURN	101	20.3	20.4	24.9	18.4	15.4
Cardiff AURN	102	21.1	20.0	24.9	18.4	15.9
Cardiff AURN	103	20.7	19.8	24.9	18.4	15.7
30 Caerphilly Road	106	29.4	26.6	31.3	24.6	23.1
Lynx Hotel	107	30.7	**N/A**	29.0	21.6	22.7
98 Leckwith Road	111	21.3	**N/A**	19.6	15.3	16.6
17 Sloper Road	112	27.1	26.5	21.9	17.2	21.3
21 Llandaff Road	115	32.5	29.2	19.1	15.2	26.1
25 Cowbridge Road West	117	39.5	39.8	26.6	20.0	29.9
Havelock Street	119	27.7	37.9	32.2	22.3	19.6
287 Cowbridge Road East	124	22.5	**N/A**	18.7	14.4	17.2
Westgate Street Flats	126	36.0	35.2	37.9	27.6	26.3
117 Tudor Street	128	29.6	27.7	21.4	16.1	21.7
Stephenson Court 2	129	31.5	**N/A**	34.4	23.9	22.2
Burgess Court	130	35.2	**N/A**	35.3	24.5	24.4
Dragon Court	131	39.5	38.6	35.6	24.7	27.1
St Mark's Avenue	133	31.9	**N/A**	35.8	28.1	24.9
Sandringham Hotel	134	32.1	34.3	26.5	18.8	22.2

Lower Cathedral Road	139	29.4	**N/A**	26.1	19.8	22.2
Clare Street	140	36.3	**N/A**	27.7	21.2	27.7
Fairoak Road 2	141	32.3	**N/A**	24.1	18.9	25.5
Windsor House	143	38.2	37.5	38.6	27.9	27.6
Marlborough House	144	37.2	34.7	38.2	26.6	26.0
Tudor Street Flats	145	29.9	28.3	35.5	24.3	20.8
Neville Street	146	26.6	**N/A**	25.5	19.8	20.6
211 Penarth Road	147	27.7	26.9	22.2	17.5	21.9
161 Clare Road	148	27.5	26.8	22.7	18.0	21.9
10 Corporation Road	149	33.6	31.2	20.9	16.5	26.5
James Street	152	27.6	30.3	26.3	22.0	23.1
Magic Roundabout	153	29.0	24.8	29.7	21.6	21.2
2a/4 Colum Road	156	25.9	25.8	24.2	18.5	19.7
47 Birchgrove Road	157	27.2	24.2	26.7	20.8	21.2
64/66 Cathays Terrace	158	25.5	24.3	23.2	18.0	19.7
IMO façade replacement	159	34.0	33.6	31.6	22.6	24.2
High Street Zizzi	160	27.0	25.7	28.2	20.6	19.8
52 Bridge Road	161	32.3	**N/A**	24.3	18.9	25.2
58 Cardiff Road	162	24.5	**N/A**	22.7	18.0	19.4
118 Cardiff Road	163	23.2	**N/A**	24.9	19.4	18.1
725 Newport Road	164	20.3	**N/A**	20.9	16.6	16.1
6 Heol Tyrrell	165	15.1	**N/A**	16.7	13.2	11.9
163 Lansdowne Road	166	32.1	30.3	21.3	16.9	25.5
359 Lansdowne Road	167	28.3	27.5	22.0	17.0	21.7

570 Cowbridge Road East	168	24.3	25.1	24.3	18.7	18.7
11 Pengam Green	170	19.1	**N/A**	23.0	17.6	15.0
23 Tweedsmuir Road	171	18.1	**N/A**	22.2	17.9	15.0
Ocean Way 1	172	**44.5**	**N/A**	28.6	18.9	24.4
Ocean Way 2	173	28.4	**N/A**	29.5	19.6	19.2
76 North Road	174	28.7	27.7	32.8	23.9	20.9
Castle Arcade	176	**47.8**	**N/A**	**57.8**	**42.7**	36.8
Angel Hotel	177	**48.1**	**N/A**	**44.8**	33.1	35.6
Park Street/Westgate Street	178	**45.4**	**N/A**	**52.7**	32.0	27.8
New sites added after 2015						
Altolusso, Bute Terrace	179	**N/A**	**44.5**	33.8	26.3	**N/A**
Station Terrace	183	**N/A**	31.1	**46.6**	32.1	**N/A**
Hophouse, St Mary Street	184	**N/A**	40.2	**43.7**	29.3	**N/A**
Northgate House, Duke Street	185	**N/A**	32.7	38.6	27.2	**N/A**
Dempsey's Public House, Castle Street	186	**N/A**	**46.5**	**54.7**	**40.5**	**N/A**
Angel Hotel	187	**N/A**	**45.1**	**44.4**	32.8	**N/A**
Westgate Street (45 Apartments)	188	**N/A**	**50.5**	**58.1**	35.1	**N/A**
3 Pearson Street	190	**N/A**	22.3	21.5	16.5	**N/A**
7 Mackintosh Place	191	**N/A**	29.1	30.8	23.7	**N/A**
3 Cowbridge Road West	192	**N/A**	39.2	24.8	18.8	**N/A**
24 Kings Road	193	**N/A**	17.4	26.5	20.1	**N/A**
115 Cowbridge Road West	194	**N/A**	21.5	22.2	16.6	**N/A**
244 Newport Road	195	**N/A**	31.4	33.7	24.8	**N/A**
2 Pencisely Road	196	**N/A**	23.8	23.1	18.1	**N/A**

GFF 369 Newport Road	197	**N/A**	31.1	26.7	20.1	**N/A**
Next Building to Stephenson Court	198	**N/A**	35.3	27.3	20.0	**N/A**
157 Newport Road	199	**N/A**	23.9	27.3	20.0	**N/A**
350 Whitchurch Road	200	**N/A**	32.7	32.9	25.7	**N/A**
23 Lower Cathedral Road	201	**N/A**	29.2	24.3	18.4	**N/A**
22 Clare Street	202	**N/A**	27.4	25.6	19.6	**N/A**
10 Fairoak Road	203	**N/A**	20.6	20.6	16.3	**N/A**
53 Neville Street	204	**N/A**	22.4	21.8	16.8	**N/A**
Fitzalan Court, Newport Road	205	**N/A**	**47.4**	30.1	22.1	**N/A**
Windsor House, Windsor Lane	206	**N/A**	**50.4**	29.6	21.9	**N/A**
42 Waungron Road	207	**N/A**	21.3	20.0	15.6	**N/A**
2 Llantrisant Road	208	**N/A**	25.1	22.5	17.7	**N/A**
178 North Road	209	**N/A**	21.7	31.1	22.7	**N/A**
485 Caerphilly Road	210	**N/A**	20.7	25.2	19.6	**N/A**
19 Well Wood Close, Penylan	211	**N/A**	20.4	22.1	17.2	**N/A**
62 Bridge Road	212	**N/A**	**47.8**	29.6	22.9	**N/A**

[1]- These monitoring locations were commissioned after 2015 and consequently there are no measured 2015 concentrations, or site specific adjusted concentrations. 2 – The 2018 measured concentrations are not based upon a full years monitoring data, these concentrations may change.

3.3 Source apportionment

For 2015 and 2021 base years we carried out source apportionment for a number of locations in Cardiff to provide an indication of the key sources contributing to pollution levels. The locations selected for source apportionment are the PCM receptor showing persistent exceedance in 2021 on Castle Street, along with monitoring locations close to this location. The locations for which source apportionment have been calculated are indicated in Figure 9 below.

Figure 9: Location of source apportionment results

3.3.1 2015 baseline source apportionment

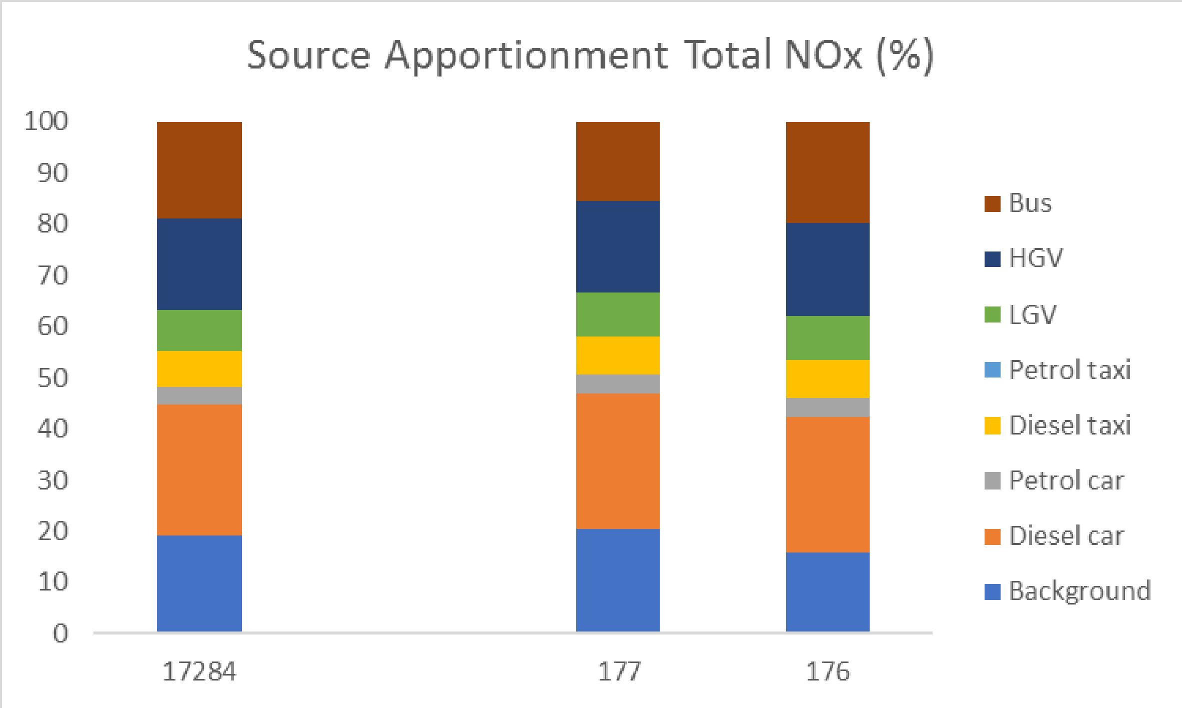
The source apportionment results (in terms of NOx concentrations) for 2015 are shown in Table 12. These show that the main source of air pollution is from road traffic, which accounts for 80 - 84 %, while the remainder of the pollution is from background sources.

Table 12: NOx concentrations in 2015 (µg/m3)

Site name	PCM census link	Background		Roads		Total
		µg/m³	%	µg/m³	%	
PCM_17284	30665	21.7	19.1%	91.7	80.9%	113.4
DT176	30665	16.3	20.3%	63.7	79.7%	80.0
DT177	30665	16.9	15.8%	90.0	84.2%	106.9

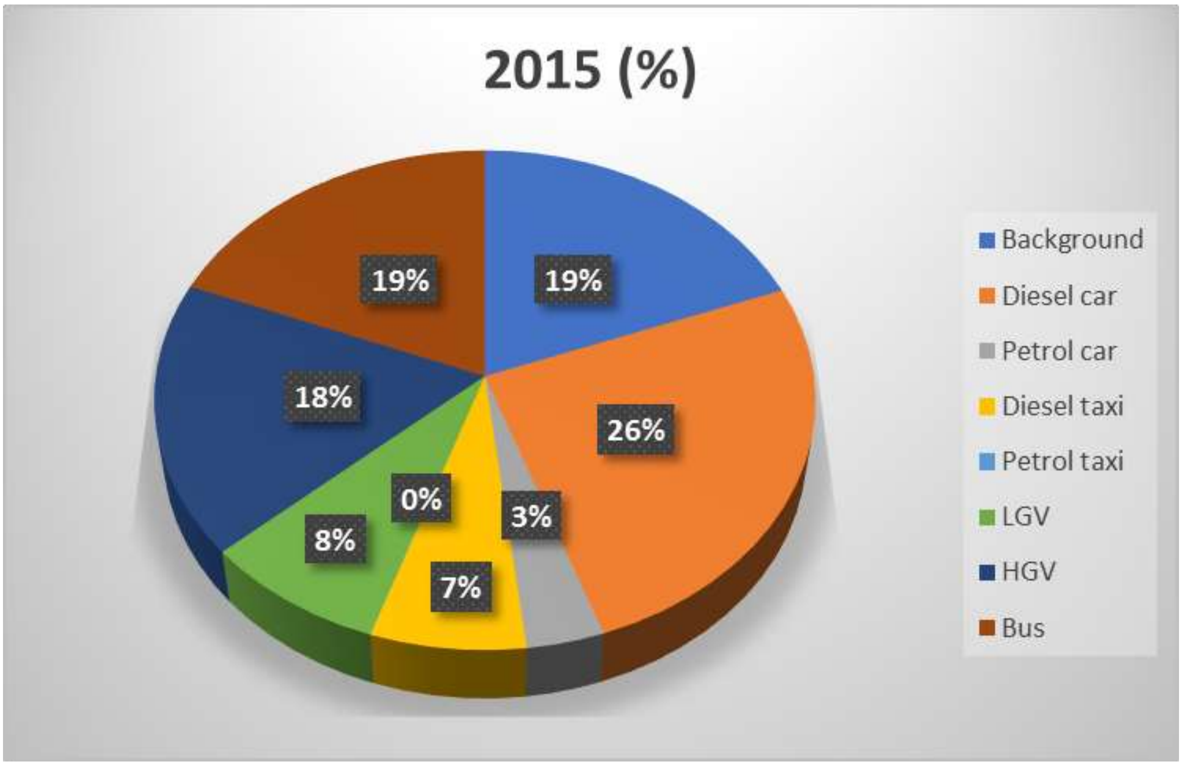
The road contribution can be broken down further to show the contribution from each vehicle type, as illustrated in Figure 10: Source apportionment of total NOx (%) at each of the locations along PCM link 30665. Overall, diesel cars are the main contributor followed by buses and HGVs. Taxis account for between 5 and 10 % of NOx emissions, while buses on account for between 8 and 10 % of NOx.

Figure 10: Source apportionment of total NOx (%) at each of the locations along PCM link 30665



The source apportionment for the three locations on 30665 is similar, therefore for the remainder of the report the source apportionment for 17284 only will be presented. Figure 11 presents the results of 17284 in form of a pie chart to aid comparison between 2015 and the future year results presented.

Figure 11: Breakdown of NOx contribution in 2015



3.3.2 2021 baseline source apportionment

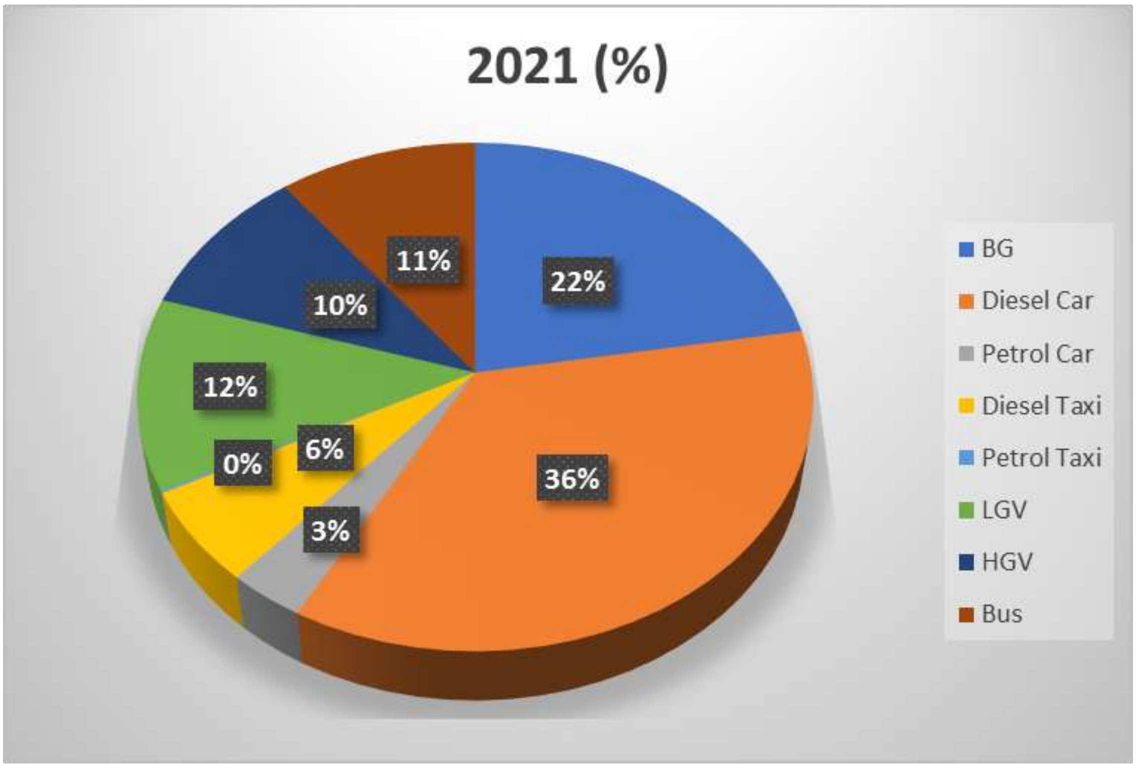
The 2021 source apportionment results for NOx are shown in Table 13. In 2021 the main contribution to pollution in Cardiff is still anticipated to be road traffic (73 – 78 %).

Table 13: NOx concentrations in 2021 (μg/m3)

Site name	PCM census link	Background μg/m³	Background %	Roads μg/m³	Roads %	Total
PCM_17284	30665	16.9	22.3%	58.8	77.7%	75.7
DT176	30665	16.3	27.3	43.0	72.7%	59.3
DT177	30665	17.0	22.8	57.5	77.2%	74.5

The breakdown of the projected 2021 road NOx concentrations by vehicle type is given in Figure 12. In 2021 diesel cars still contribute the largest proportion of emissions to the total road NOx emissions while the proportion of emissions from HGVs and buses has reduced.

Figure 12: Breakdown of NOx contribution in 2021



3.4 Model uncertainty

The city-wide model used to predict NO_2 concentrations is a large and complex model comprising many thousands of road links, a large amount of input data and a number of modelling assumptions. Both the transport and air quality modelling teams have followed all the appropriate guidance to produce as robust a model as possible. However, it needs to be recognised there is always inherent uncertainly in such models and this needs to be taken in consideration when interpreting the results. Both the transport and air quality models have been validated. In terms of the air quality model a direct assessment of uncertainty is carried out for the baseline model year (2015) as part of the validation process against monitored air quality data. In this process model performance and uncertainty is assessed using the Root Mean Square Error (RMSE) for the observed vs predicted NO_2 annual mean concentrations, as detailed in Technical Guidance LAQM.TG(16). In this case the RMSE was calculated at 5.1 µg.m-3. This can then be used as a measure of error on forecast results for future years. This error metric has been used when considering the results by considering locations over 35 µg.m^{-3} as being at risk of exceedance. More details on this validation exercise can be found in Appendix 1: Air quality model verification and adjustment.

However, when assessing future years there will also be uncertainty related to the forecast assumptions we have made in modelling future years. The key assumptions relate to:

- The forecast of traffic activity in the traffic model which is related to local development factors and national growth factors;
- Forecasting the local fleet composition from the ANPR data to future years, which has been done using national trends.

One particular area of forecasting that bears further exploration is the use of the split transport model in 2021 with compliant and non-compliant vehicles. This split is not used for the 2015 traffic modelling. As such we are not strictly comparing like with like going from 2015 to 2021. However, going forward an assessment of additional scenarios taking account of expected policy options will be carried out, and for this we will need to use the split matrix transport model. It will therefore be more robust to compare these option results with the baseline 2021 results using the split model as well. Splitting the transport model in this way can influence both the traffic flows and speeds and the fleet composition on individual links when comparing with an un-split model. To assess the impact of this we plan to do a sensitivity test by running the unsplit 2021 transport model results through the air quality model and comparing this with the current 2015 and 2021 results.

Another area of uncertainly is the emissions data used in the modelling. We have used the latest COPERT emission factors available in line with guidance, however, we are aware that these do not always reflect 'real world' vehicle performance accurately. For example, remote sensing work carried out by Ricardo has shown that LGV emissions, particularly for Euro 5 vehicles, can be significantly higher than the standard emission factors. There is also significant variation within a Euro class. This uncertainty also relates to the primary NO_2 fraction (fNO_2) which can have implications for the NOx to NO_2 conversion process used in the modelling as it can be quite sensitive to fNO_2. Again, we have followed the current guidance on this and used a link-specific fNO_2 derived from modelled primary NO_2 and NOx concentrations at each location.

Lastly, the PCM results have been extracted using the 4m buffer as described above, as per guidance. However, in defining relevant receptors along the 4m buffer we also have to account for several other key criteria:

- The receptor location should be representative of 100m length of road;
- It should not be closer than 25m to a major road junction;
- There must be public access – such as a footpath or building.

The sampling is done automatically in a GIS system and the above exceptions removed manually. However, there is some subjectivity around these exceptions such as what constitutes a major junction and how publicly accessible are certain locations. The final results allocated to any given PCM link can be quite sensitive to the final selection of receptors. However, we have taken all endeavours to ensure the final set of receptors used is a reasonable interpretation of the criteria given in the guidance.

4 Scenario results

Each of the scenario model runs have been carried out using the assumptions set out in section 2. The results have been extracted in the same way as for the baseline and are shown in the sections below.

4.1 CASAP 1-3

The CASAP 1 scenario shows a general reduction in concentrations across the links, with an average of about 1 µgm^{-3}. The links where the largest reductions are being seen are those directly affected by the measures such as the electric bus measure. The largest reduction is actually on Castle Street where the electric buses will operate. This is also the exceedance link of concern and this scenario brings it down from 41.1 µgm^{-3} to 37.3 µgm^{-3}. Therefore, the CASAP 1 scenario is enough to bring all the PCM links into compliance.

CASAP 2 provides little further benefit in terms of NO_2 concentrations with some links improving a little but other getting worse. This appears to be driven by changes in the traffic flows caused by vehicles rerouting because of the city centre traffic management schemes and the parking controls. This will also have impacts on vehicle speeds which also affected emissions and hence concentrations.

The CASAP 3 results show that generally concentrations under CASAP 3 are lower than CASAP 2. At three links, the concentrations in CASAP 3 are the same as CASAP 2, but for all others they are lower, by between 0.1 and 1.4 µgm-3. The largest reductions in concentrations are:

- Census ID 30665 (A4161) – this is Castle Street, where the exceedances were showing up in the baseline results for 2021. As CASAP 3 measures were designed specifically to address concentrations in the city centre, it is to be expected that CASAP 3 would therefore lead to a significant decrease in concentrations at this link.
- Census ID 77018 (A470) – again, measures were introduced in CASAP 3 to specifically address NO_2 concentrations at links on the A470, so higher reductions in concentrations are expected here.
- Census ID 10629 (A4054) – it is likely that the city wide rollout of bus EURO 6 retrofits will substantially reduce bus emissions and has led to reductions in NO_2 concentrations at this link.

The results are shown in Table 14 below. Mapped results are shown in

Table 14: PCM and local model NO_2 concentration results for CASAP 1, 2 and 3 in 2021 (NO_2 in µgm-3)

CensusID	Road Name	PCM Baseline		Local Baseline		Clean Air Strategy Action Plan (CASAP) in 2021		
		2015	2021	2015	2021	CASAP 1	CASAP 2	CASAP 3
30660	A4119	22.4	17.9	37.1	30.7	29.7	30.2	29.7
10629	A4054	19.1	15.0	25.3	19.5	19.1	19.2	17.9
50647	A4119	29.9	24.0	34.4	24.4	23.6	27.6	26.8
10660	A4161	40.3	32.7	34.9	26.2	25.5	25.5	25.3
522	A48	27.9	22.3	32.9	25.4	24.1	24.1	24.0
30659	A4119	27.2	21.8	23.8	18.8	18.2	18.2	17.8

77018	A470	31.1	25.2	45.4	30.6	27.5	26.5	25.1
99955	A4160	32.2	25.7	36.7	26.9	25.5	25.1	24.9
50660	A4161	43.7	33.8	42.2	30.8	28.8	28.3	27.8
70055	A4161	37.5	29.7	43.9	30.4	28.1	27.3	26.9
99671	A469	33.1	27.1	27.2	21.5	20.7	20.7	20.4
10659	A4160	30.4	25.0	30.4	23.7	22.6	22.3	22.3
10655	A4119	31.9	25.9	36.6	29.0	27.5	27.5	26.8
80898	A4232	47.3	37.7	34.3	29.5	28.0	28.3	28.2
20527	A48	48.8	39.1	40.0	30.6	31.3	31.6	31.5
40655	A4160	28.2	22.7	24.2	19.3	18.9	18.6	18.5
50580	A469	28.5	22.4	33.0	25.8	24.8	24.8	24.6
50657	A4161	29.5	23.3	26.5	20.3	19.6	19.6	19.3
10661	A4161	24.9	20.1	26.6	20.2	19.5	19.9	19.8
10527	A48	31.9	25.7	29.4	22.7	21.9	22.0	21.7
40582	A469	31.8	25.5	32.2	24.7	24.5	24.3	24.0
50651	A4119	28.4	22.9	31.6	24.5	23.5	23.9	23.8
40656	A4161	40.9	33.4	43.7	29.6	28.1	28.0	27.6
40549	A470	40.8	32.5	38.1	27.6	26.1	25.6	25.2
50527	A48	45.3	37.1	37.1	28.8	28.0	28.2	28.0
642	A4160	38.3	32.1	40.0	28.8	27.8	30.0	29.8
80899	A4232	43.1	34.3	32.1	27.5	26.8	27.2	27.1
99960	A4055	34.9	28.4	31.4	25.5	24.0	24.1	24.1
50541	A470	35.6	28.5	37.3	29.1	28.3	28.2	28.0
20548	A470	31.3	24.6	41.3	30.0	27.9	27.8	27.3
50524	A48	59.6	45.4	36.4	27.9	27.6	27.6	27.5
74101	A4232	52.5	40.7	30.1	24.8	22.9	23.0	23.0
638	A4119	27.5	21.6	28.8	22.3	21.6	21.7	21.4
30665	A4161	41.2	31.9	55.7	41.1	37.3	36.0	35.0
73233	A4055	35.8	29.1	31.6	24.5	23.4	23.4	23.3
99956	A4234	44.6	36.8	38.2	26.3	25.4	26.3	26.2
78439	A4232	33.6	26.4	21.7	17.5	17.3	17.4	17.3
70056	A4232	42.2	29.9	35.3	28.9	29.6	29.8	29.7
73232	A4160	26.9	21.2	21.0	18.1	16.3	16.4	16.3
80896	A470	26.5	22.2	26.9	21.8	21.4	21.9	21.7
80726	A470	35.4	25.3	34.8	25.2	23.3	23.0	22.4
78435	A4050	30.2	23.1	32.5	25.0	24.1	24.3	24.2

Figure 13 PCM links colour coded with CASAP 1 results in 2021

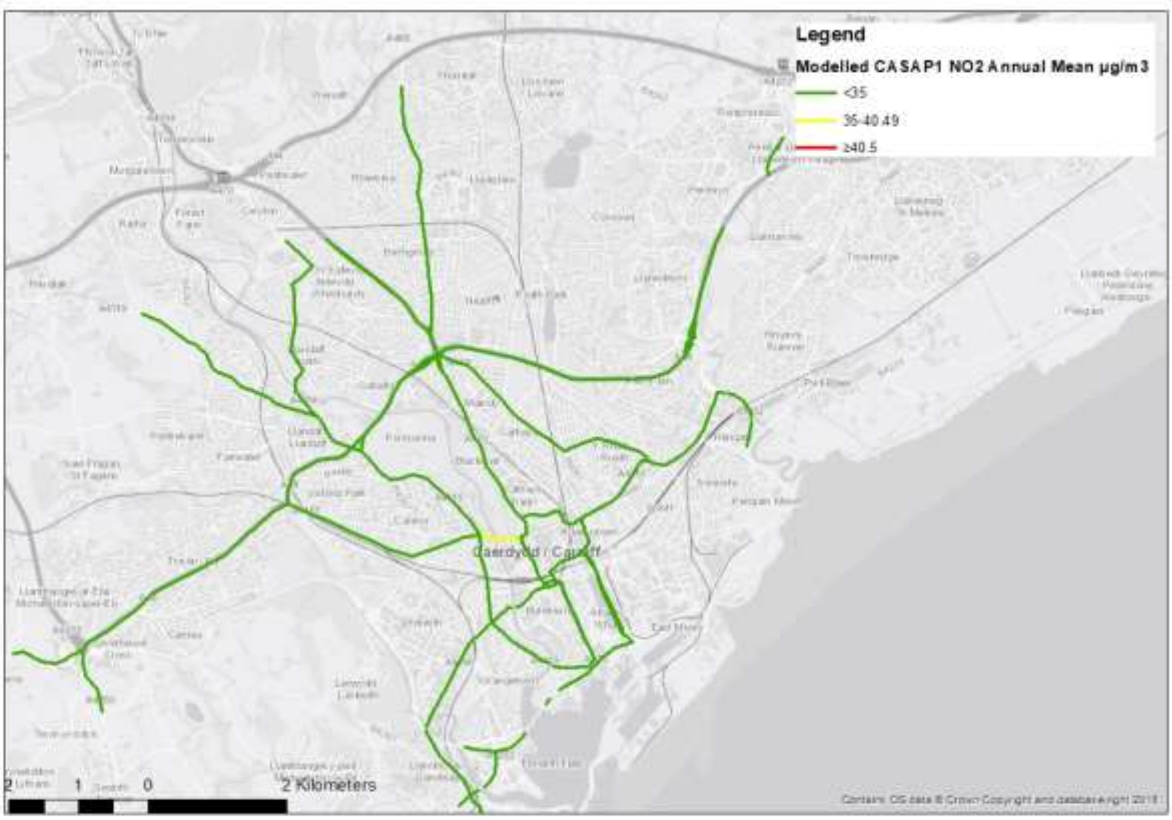


Figure 14 Sampled NO_2 results along the PCM links > 35 µgm^{-3} for CASAP 1 in 2021

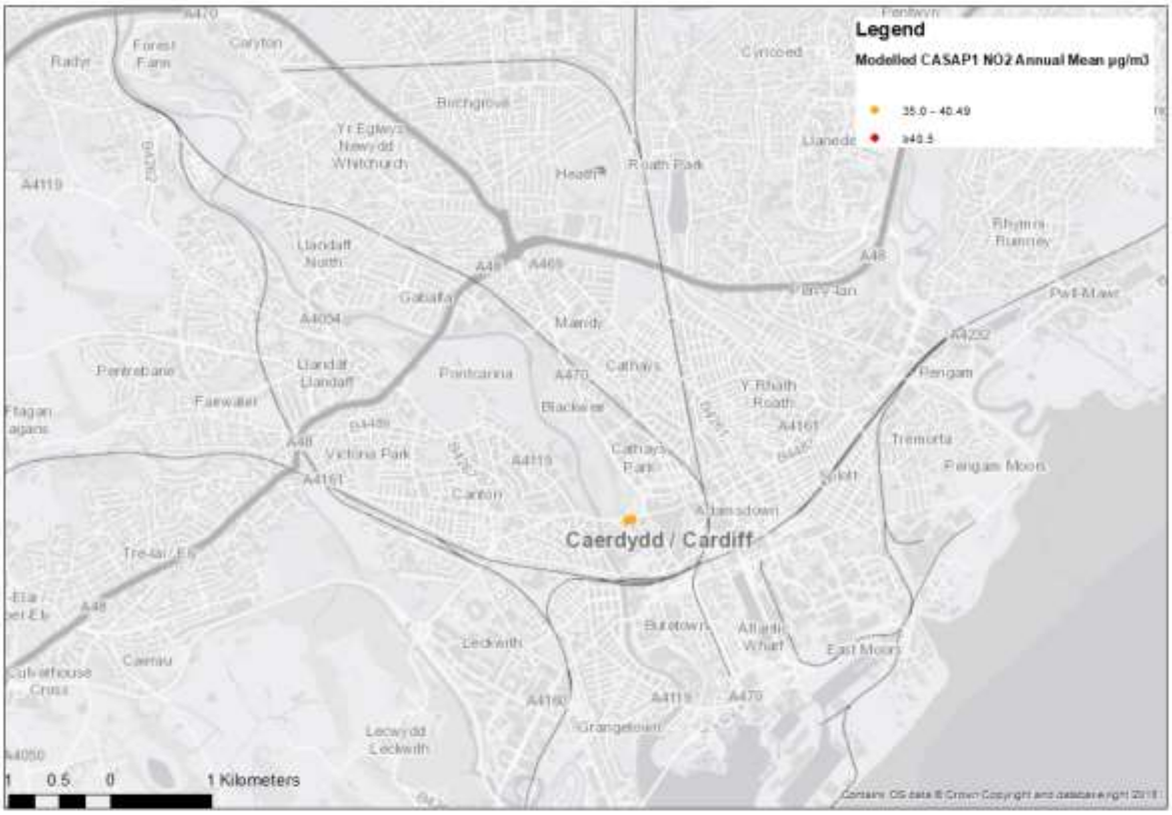


Figure 15 PCM links colour coded with CASAP 2 results for 2021

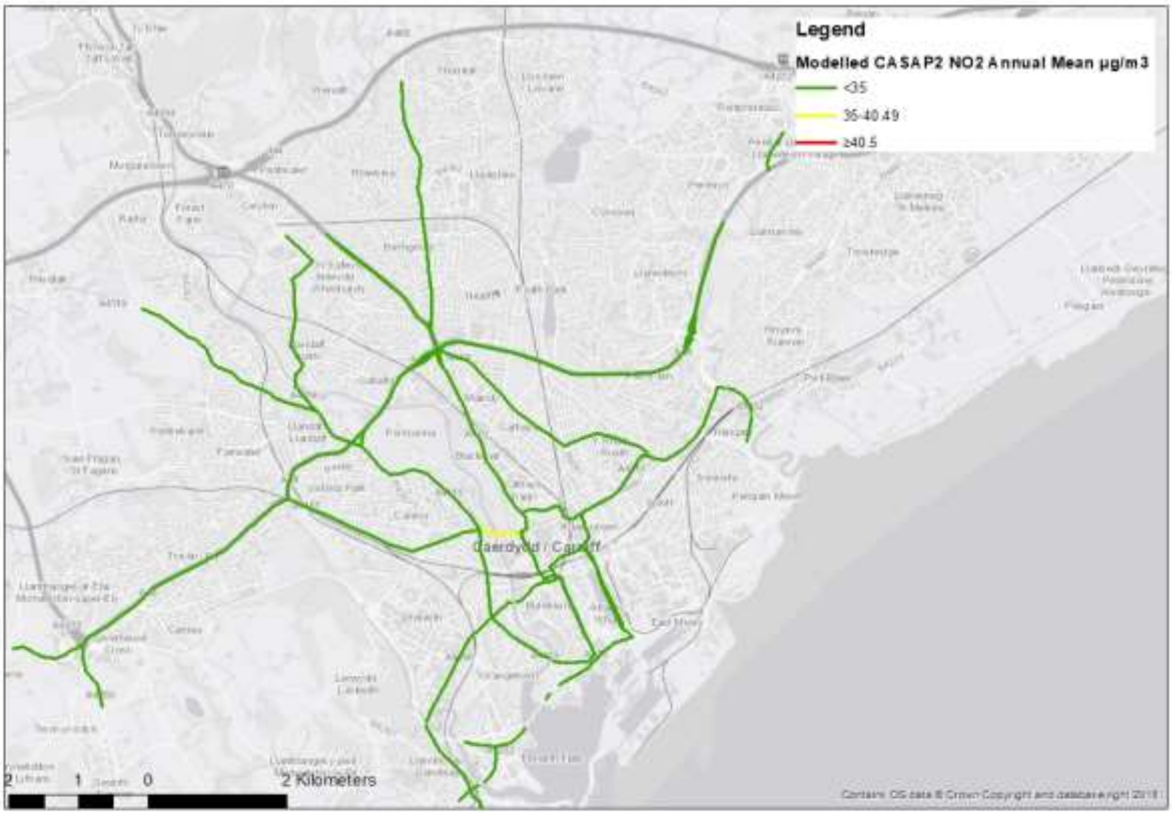


Figure 16 Sampled NO_2 results along the PCM links > 35 µgm^{-3} for CASAP 2 in 2021

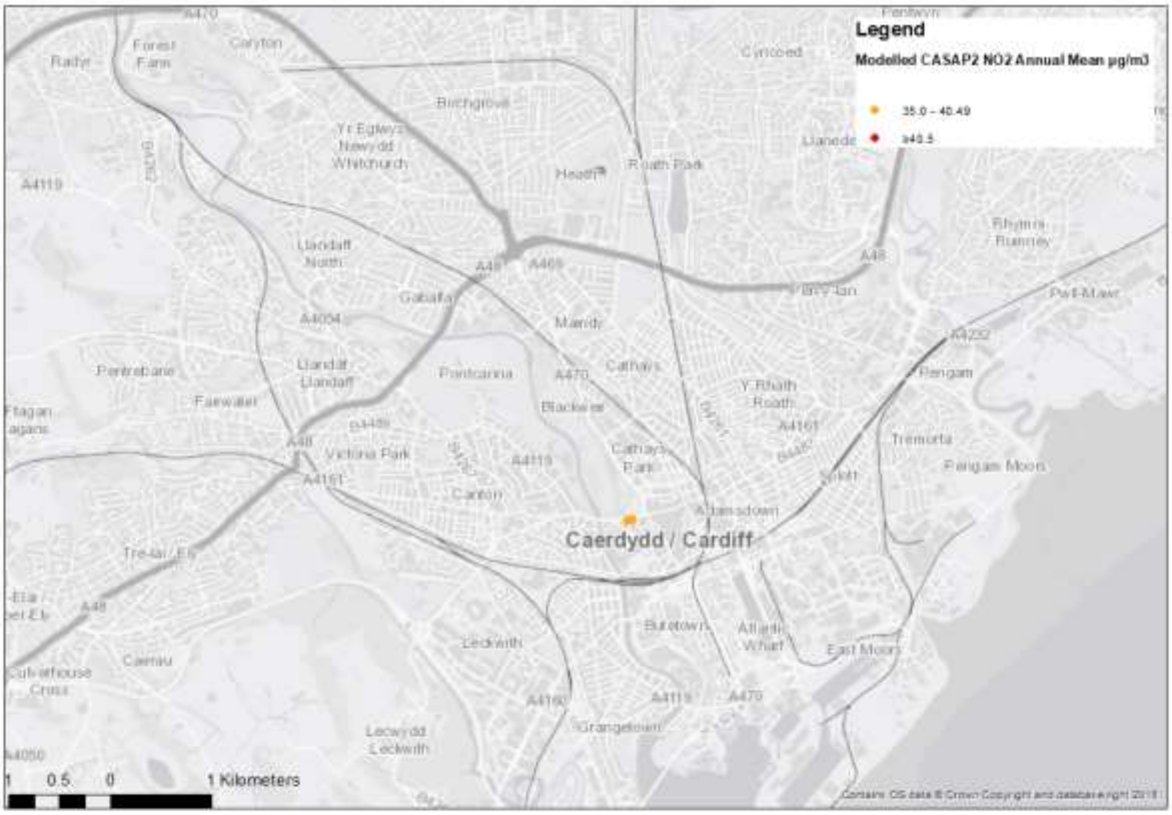


Figure 17: PCM links colour coded with CASAP 3 results in 2021

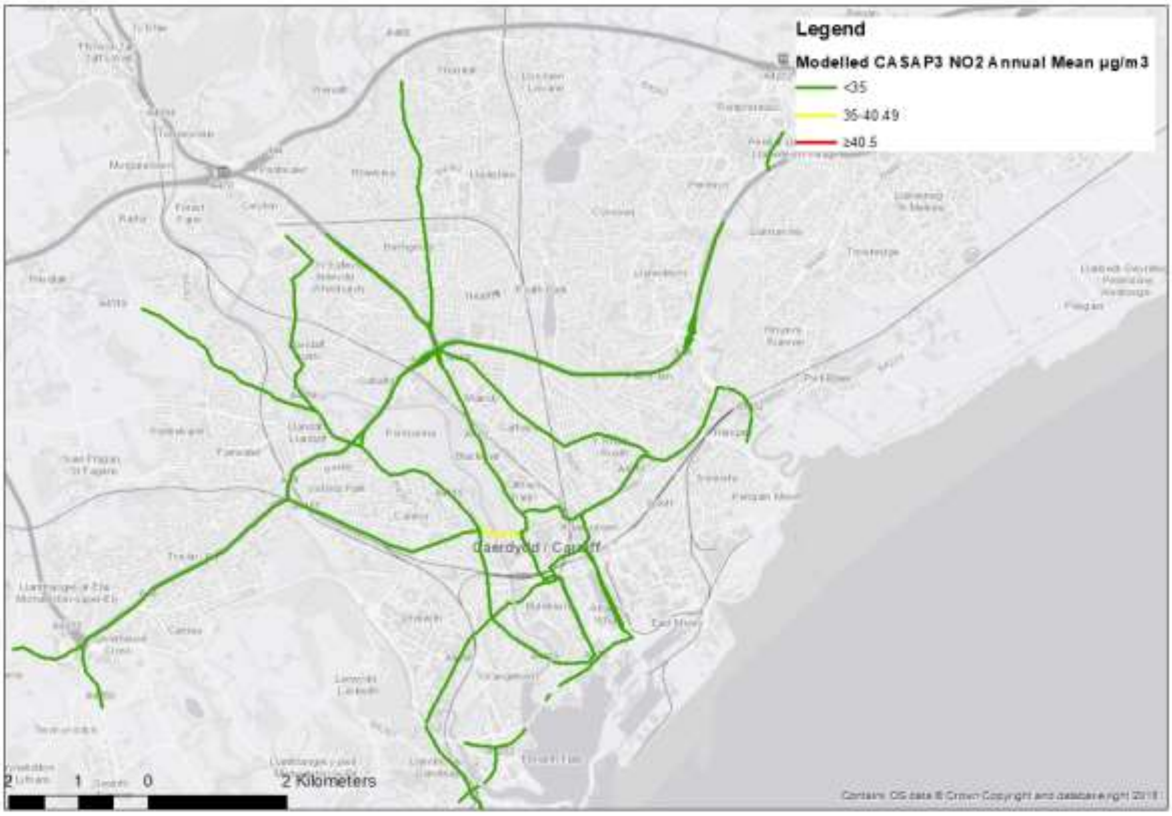


Figure 18: Sampled NO_2 results along the PCM links > 35 µgm-3 for CASAP 3 in 2021

4.2 Preferred CASAP scenario

In line with the modelled results for the other scenarios, the results for the preferred CASAP scenario have been generated for each of the PCM road links. This has been done in exactly the same way as the previous air quality modelling. A full list of tabulated results for the PCM road links for the modelled years of 2015 and 2021 is shown in Table 15. Concentrations for intervening years have been calculated through interpolation. The concentrations are shown against the concentrations for those PCM links calculated by the PCM model. Mapped results from the local modelling study on PCM links are shown in Figure 19. A figure of local modelling results at PCM equivalent sampling points has not been included as all sampling points are below 35 µgm-3.

Table 15 shows that the preferred CASAP scenario gives lower concentrations than the PCM model for all but 8 of the 42 links. For the 8 links where concentrations are higher, they are generally only slightly higher (<3 µgm-3) but the exception is link ID 30660 (A4119) where the locally modelled concentration is much higher than the PCM value.

Table 16 compares the results against the other CASAP scenarios. It shows that the preferred CASAP scenario gives lower concentrations for the majority of links compared to other CASAP scenarios (between 76% and 93% of the links show lower concentrations in the preferred scenario than in the CASAP 2-3). The exception is the comparison with CASAP 1, where the preferred scenario shows just over half of the links with higher concentrations than in CASAP 1, likely due to diversionary effects of the city centre traffic scheme.

A few links stand out as showing higher concentrations under the preferred CASAP scenario compared to other scenarios, again likely to be due to diversionary effects of the city centre traffic scheme:

- Census ID 99955 (A4160) and 40582 (A469) – concentrations higher in the preferred scenario than in all the other scenarios.
- Census ID 522 (A48), 80898 (A4232) and 73232 (A4160) – concentrations higher in the preferred scenario than in the CASAP 1-3 scenarios.
- Census ID 99956 (A4234) – concentration higher in the preferred scenario than in the CASAP 1 and 3 scenarios, but lower than the CASAP 2 scenario.

Table 15: PCM and local model NO2 concentration results for the preferred CASAP scenario in 2015 and 2021 (NO2 in µgm-3), with intervening years interpolated

Census ID	Road Name	PCM Baseline						2021 FBC CASAP						
		2015	2017	2018	2019	2020	2021	2015	2016	2017	2018	2019	2020	2021
30660	A4119	22.4	21.3	20.5	19.8	18.9	17.9	37.1	35.9	35.7	35.3	34.7	33.6	30.1
10629	A4054	19.1	18.1	17.4	16.7	15.8	15.0	25.3	24.0	23.8	23.4	22.8	21.5	17.7
50647	A4119	29.9	28.7	27.7	26.7	25.4	24.0	34.4	32.3	31.9	31.3	30.3	28.3	22.2
10660	A4161	40.3	38.7	37.4	36.2	34.5	32.7	34.9	33.3	33.0	32.5	31.7	30.1	25.4
522	A48	27.9	26.8	25.8	24.8	23.7	22.3	32.9	31.5	31.2	30.7	30.0	28.6	24.4
30659	A4119	27.2	26.2	25.2	24.3	23.1	21.8	23.8	22.8	22.6	22.3	21.7	20.7	17.6
77018	A470	31.1	29.8	28.7	27.7	26.4	25.2	45.4	41.9	41.1	40.1	38.3	34.7	24.1
99955	A4160	32.2	30.7	29.6	28.5	27.1	25.7	36.7	35.0	34.6	34.1	33.2	31.4	26.1
50660	A4161	43.7	41.4	39.6	37.9	35.9	33.8	42.2	39.4	38.8	38.0	36.6	33.8	25.4
70055	A4161	37.5	35.9	34.5	33.1	31.5	29.7	43.9	41.0	40.5	39.6	38.2	35.3	26.6
99671	A469	33.1	32.2	31.1	30.1	28.7	27.1	27.2	26.0	25.7	25.4	24.8	23.6	20.0
10659	A4160	30.4	29.3	28.3	27.3	26.2	25.0	30.4	28.9	28.6	28.1	27.4	25.9	21.4
10655	A4119	31.9	30.8	29.8	28.8	27.4	25.9	36.6	34.9	34.6	34.1	33.2	31.5	26.3
80898	A4232	47.3	45.2	43.5	42.0	39.9	37.7	34.3	33.4	33.2	32.9	32.4	31.5	28.6
20527	A48	48.8	46.9	45.2	43.6	41.5	39.1	40.0	38.6	38.3	37.9	37.1	35.7	31.4
40655	A4160	28.2	27.1	26.1	25.1	24.0	22.7	24.2	23.1	22.9	22.6	22.1	21.0	17.7
50580	A469	28.5	27.1	26.1	25.0	23.8	22.4	33.0	31.5	31.2	30.8	30.1	28.6	24.2
50657	A4161	29.5	28.3	27.2	26.1	24.8	23.3	26.5	25.2	25.0	24.6	24.0	22.7	19.0
10661	A4161	24.9	23.9	23.1	22.2	21.2	20.1	26.6	25.3	25.1	24.7	24.0	22.7	18.8
10527	A48	31.9	30.8	29.6	28.6	27.2	25.7	29.4	28.1	27.8	27.5	26.8	25.5	21.7
40582	A469	31.8	30.5	29.5	28.4	27.0	25.5	32.2	31.0	30.8	30.4	29.8	28.6	25.1
50651	A4119	28.4	27.3	26.4	25.5	24.2	22.9	31.6	30.3	30.1	29.7	29.1	27.8	24.0
40656	A4161	40.9	39.3	38.0	36.8	35.1	33.4	43.7	41.0	40.5	39.7	38.3	35.7	27.6
40549	A470	40.8	39.1	37.7	36.3	34.5	32.5	38.1	35.7	35.2	34.5	33.3	30.9	23.8
50527	A48	45.3	44.0	42.6	41.2	39.3	37.1	37.1	35.5	35.2	34.7	33.9	32.3	27.5

642	A4160	38.3	37.1	36.1	35.0	33.6	32.1	*40.0*	*37.9*	*37.5*	*36.8*	*35.8*	*33.7*	*27.4*
80899	A4232	43.1	41.1	39.5	38.1	36.3	34.3	*32.1*	*31.2*	*31.1*	*30.8*	*30.4*	*29.5*	*26.9*
99960	A4055	34.9	33.7	32.6	31.5	30.0	28.4	*31.4*	*30.2*	*30.0*	*29.6*	*29.0*	*27.7*	*24.0*
50541	A470	35.6	34.1	32.9	31.8	30.2	28.5	*37.3*	*35.6*	*35.2*	*34.7*	*33.9*	*32.2*	*27.1*
20548	A470	31.3	29.8	28.6	27.5	26.1	24.6	*41.3*	*38.4*	*37.8*	*37.0*	*35.5*	*32.6*	*23.8*
50524	A48	59.6	56.2	53.7	51.4	48.5	45.4	*36.4*	*34.8*	*34.5*	*34.1*	*33.3*	*31.7*	*27.1*
74101	A4232	52.5	49.7	47.6	45.7	43.3	40.7	*30.1*	*29.0*	*28.8*	*28.4*	*27.9*	*26.8*	*23.4*
638	A4119	27.5	26.1	25.0	24.0	22.8	21.6	*28.8*	*27.3*	*27.0*	*26.6*	*25.8*	*24.3*	*19.8*
30665	A4161	41.2	39.0	37.3	35.7	33.9	31.9	*55.7*	*51.7*	*50.9*	*49.7*	*47.7*	*43.8*	*31.9*
73233	A4055	35.8	34.6	33.4	32.3	30.8	29.1	*31.6*	*30.2*	*29.9*	*29.4*	*28.7*	*27.2*	*22.8*
99956	A4234	44.6	43.1	41.8	40.5	38.7	36.8	*38.2*	*36.3*	*35.9*	*35.3*	*34.3*	*32.4*	*26.6*
78439	A4232	33.6	32.0	30.7	29.5	28.1	26.4	*21.7*	*20.9*	*20.8*	*20.6*	*20.2*	*19.4*	*17.0*
70056	A4232	42.2	38.2	36.0	34.0	32.0	29.9	*35.3*	*34.0*	*33.7*	*33.3*	*32.7*	*31.4*	*27.5*
73232	A4160	26.9	25.6	24.6	23.6	22.5	21.2	*21.0*	*20.4*	*20.3*	*20.1*	*19.8*	*19.2*	*17.4*
80896	A470	26.5	25.3	24.5	23.8	22.9	22.2	*26.9*	*26.0*	*25.8*	*25.5*	*25.1*	*24.2*	*21.6*
80726	A470	35.4	32.6	30.9	29.1	27.2	25.3	*34.8*	*32.5*	*32.0*	*31.3*	*30.2*	*27.8*	*20.8*
78435	A4050	30.2	28.5	27.2	26.0	24.6	23.1	*32.5*	*31.1*	*30.8*	*30.4*	*29.7*	*28.3*	*24.2*

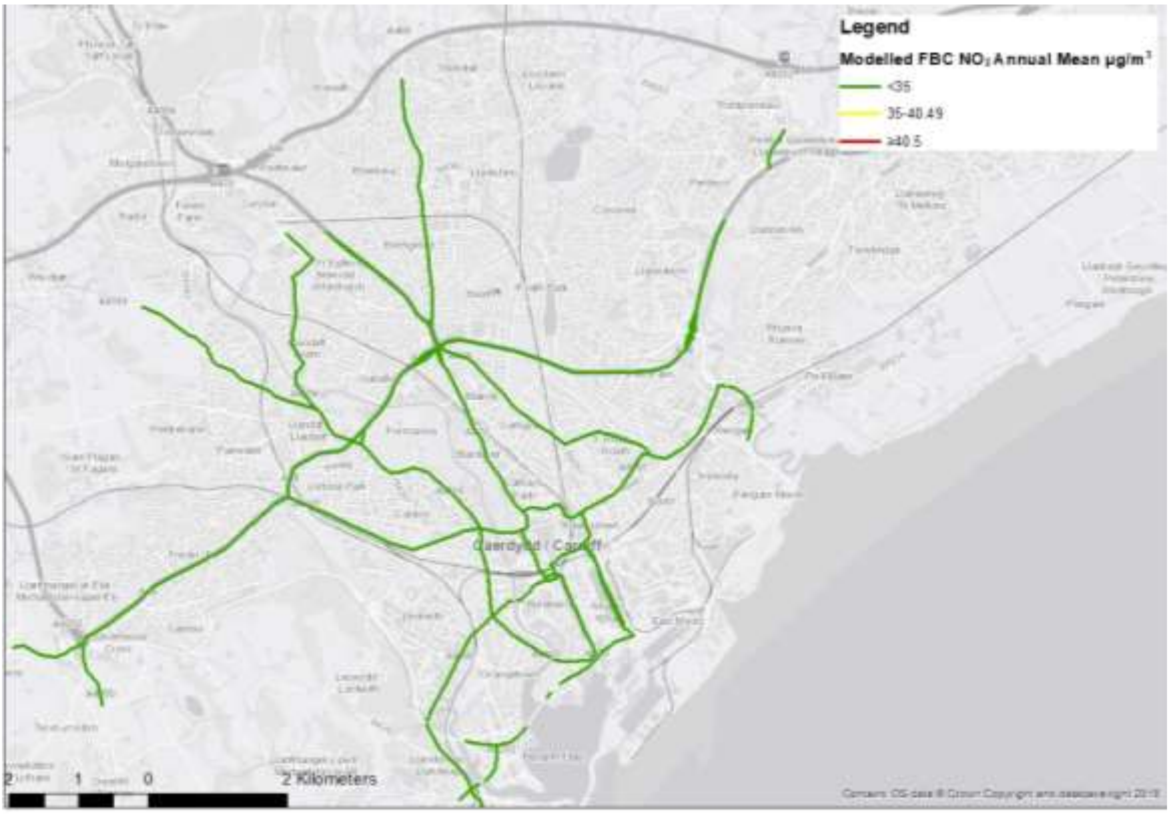
Note: local results are colour coded as green for less than 35µgm^{-3}, amber between 35µgm^{-3} and 40 µgm^{-3} and red for greater the 40µgm^{-3} (the compliance threshold). Numbers are rounded to the nearest integer, hence any values less than 40.5 µgm^{-3} are not counted as exceedances.

Table 16: local model NO2 concentration results for the preferred CASAP scenario in 2021 (NO2 in µgm-3), compared to 2021 results in other CASAP scenarios

Census ID	Road Name	PCM Baseline		Local Baseline		Clean Air Strategy Action Plan (CASAP) scenarios (2021)			
		2015	2021	2015	2021	CASAP1	CASAP2	CASAP3	Preferred option
30660	A4119	22.4	17.9	37.1	30.7	29.7	30.2	29.7	30.1
10629	A4054	19.1	15.0	25.3	19.5	19.1	19.2	17.9	17.7
50647	A4119	29.9	24.0	34.4	24.4	23.6	27.6	26.8	22.2
10660	A4161	40.3	32.7	34.9	26.2	25.5	25.5	25.3	25.4
522	A48	27.9	22.3	32.9	25.4	24.1	24.1	24.0	24.4
30659	A4119	27.2	21.8	23.8	18.8	18.2	18.2	17.8	17.6
77018	A470	31.1	25.2	45.4	30.6	27.5	26.5	25.1	24.1
99955	A4160	32.2	25.7	36.7	26.9	25.5	25.1	24.9	26.1
50660	A4161	43.7	33.8	42.2	30.8	28.8	28.3	27.8	25.4
70055	A4161	37.5	29.7	43.9	30.4	28.1	27.3	26.9	26.6
99671	A469	33.1	27.1	27.2	21.5	20.7	20.7	20.4	20.0
10659	A4160	30.4	25.0	30.4	23.7	22.6	22.3	22.3	21.4
10655	A4119	31.9	25.9	36.6	29.0	27.5	27.5	26.8	26.3
80898	A4232	47.3	37.7	34.3	29.5	28.0	28.3	28.2	28.6
20527	A48	48.8	39.1	40.0	30.6	31.3	31.6	31.5	31.4
40655	A4160	28.2	22.7	24.2	19.3	18.9	18.6	18.5	17.7
50580	A469	28.5	22.4	33.0	25.8	24.8	24.8	24.6	24.2
50657	A4161	29.5	23.3	26.5	20.3	19.6	19.6	19.3	19.0
10661	A4161	24.9	20.1	26.6	20.2	19.5	19.9	19.8	18.8
10527	A48	31.9	25.7	29.4	22.7	21.9	22.0	21.7	21.7
40582	A469	31.8	25.5	32.2	24.7	24.5	24.3	24.0	25.1
50651	A4119	28.4	22.9	31.6	24.5	23.5	23.9	23.8	24.0
40656	A4161	40.9	33.4	43.7	29.6	28.1	28.0	27.6	27.6
40549	A470	40.8	32.5	38.1	27.6	26.1	25.6	25.2	23.8
50527	A48	45.3	37.1	37.1	28.8	28.0	28.2	28.0	27.5
642	A4160	38.3	32.1	40.0	28.8	27.8	30.0	29.8	27.4
80899	A4232	43.1	34.3	32.1	27.5	26.8	27.2	27.1	26.9
99960	A4055	34.9	28.4	31.4	25.5	24.0	24.1	24.1	24.0
50541	A470	35.6	28.5	37.3	29.1	28.3	28.2	28.0	27.1
20548	A470	31.3	24.6	41.3	30.0	27.9	27.8	27.3	23.8
50524	A48	59.6	45.4	36.4	27.9	27.6	27.6	27.5	27.1
74101	A4232	52.5	40.7	30.1	24.8	22.9	23.0	23.0	23.4
638	A4119	27.5	21.6	28.8	22.3	21.6	21.7	21.4	19.8
30665	A4161	41.2	31.9	55.7	41.1	37.3	36.0	35.0	31.9
73233	A4055	35.8	29.1	31.6	24.5	23.4	23.4	23.3	22.8
99956	A4234	44.6	36.8	38.2	26.3	25.4	26.3	26.2	26.6
78439	A4232	33.6	26.4	21.7	17.5	17.3	17.4	17.3	17.0
70056	A4232	42.2	29.9	35.3	28.9	29.6	29.8	29.7	27.5
73232	A4160	26.9	21.2	21.0	18.1	16.3	16.4	16.3	17.4

80896	A470	26.5	22.2	*26.9*	*21.8*	*21.4*	*21.9*	*21.7*	*21.6*
80726	A470	35.4	25.3	*34.8*	*25.2*	*23.3*	*23.0*	*22.4*	*20.8*
78435	A4050	30.2	23.1	*32.5*	*25.0*	*24.1*	*24.3*	*24.2*	*24.2*

Figure 19: Sampled NO_2 results along the PCM links for FBC in 2021



4.3 CAZ scenarios

In line with the modelled baseline and CASAP results, the results for the CAZ scenarios have been generated for each of the PCM road links. A full list of tabulated results for the PCM road links for the modelled year of 2021 is shown in Table 17, along with the baseline and CASAP 1-3 scenario results. Mapped results are shown in Figure 20: PCM links colour coded with CAZ 1 results in 2021, Figure 21 and Figure 22. Only line maps are shown for CAZ 1 as the point maps only include NO_2 annual mean concentrations above 35 µg.m^{-3}, of which there are none.

The results for CAZ 1 and 2 show that NO_2 concentrations are estimated to be lower than the baseline 2021 scenario at most links, but with CAZ 1 showing small increases on 6 links and Caz 2 showing increases on 4 links. The largest decrease observed in both CAZ 1 and 2 is at link ID 30665 (A4161, Castle Street), as might be expected for a measure that is specifically targeting the city centre. Compared to CASAP 3, most links show higher concentrations in the CAZ 1 and 2 scenarios. But this is to be expected, as the CAZ scenarios do not include any of the CASAP measures and targets a smaller geographical area. CAZ 1 achieves larger reductions along roads within the clean air zone, although CAZ 2 is estimated to have lower concentrations on most other links (32 in total).

To summarise, CAZ 1 is the most effective at addressing city centre air quality issues but does not have as big an impact elsewhere as the CASAP scenarios or CAZ 2.

Table 17: local model NO2 concentration results for the preferred CASAP scenario in 2021 (NO2 in µgm-3), compared to 2021 results in other CASAP and CAZ scenarios

Census ID	Road Name	PCM Baseline		Local Baseline		Clean Air Strategy Action Plan (CASAP) scenarios (2021)				Charging schemes (2021)	
		2015	2021	2015	2021	CASAP1	CASAP2	CASAP3	Preferred option	CAZ 1	CAZ 2
30660	A4119	22.4	17.9	37.1	30.7	29.7	30.2	29.7	30.1	30.7	30.6
10629	A4054	19.1	15.0	25.3	19.5	19.1	19.2	17.9	17.7	19.3	19.0
50647	A4119	29.9	24.0	34.4	24.4	23.6	27.6	26.8	22.2	23.5	23.6
10660	A4161	40.3	32.7	34.9	26.2	25.5	25.5	25.3	25.4	25.6	25.2
522	A48	27.9	22.3	32.9	25.4	24.1	24.1	24.0	24.4	25.1	24.7
30659	A4119	27.2	21.8	23.8	18.8	18.2	18.2	17.8	17.6	18.4	18.5
77018	A470	31.1	25.2	45.4	30.6	27.5	26.5	25.1	24.1	28.2	28.7
99955	A4160	32.2	25.7	36.7	26.9	25.5	25.1	24.9	26.1	25.4	24.9
50660	A4161	43.7	33.8	42.2	30.8	28.8	28.3	27.8	25.4	25.8	27.9
70055	A4161	37.5	29.7	43.9	30.4	28.1	27.3	26.9	26.6	27.8	28.0
99671	A469	33.1	27.1	27.2	21.5	20.7	20.7	20.4	20.0	21.1	20.7
10659	A4160	30.4	25.0	30.4	23.7	22.6	22.3	22.3	21.4	22.6	22.3
10655	A4119	31.9	25.9	36.6	29.0	27.5	27.5	26.8	26.3	27.9	27.6
80898	A4232	47.3	37.7	34.3	29.5	28.0	28.3	28.2	28.6	29.5	28.6
20527	A48	48.8	39.1	40.0	30.6	31.3	31.6	31.5	31.4	31.5	30.8
40655	A4160	28.2	22.7	24.2	19.3	18.9	18.6	18.5	17.7	18.8	18.4
50580	A469	28.5	22.4	33.0	25.8	24.8	24.8	24.6	24.2	25.5	25.2
50657	A4161	29.5	23.3	26.5	20.3	19.6	19.6	19.3	19.0	19.6	19.6
10661	A4161	24.9	20.1	26.6	20.2	19.5	19.9	19.8	18.8	19.6	19.3
10527	A48	31.9	25.7	29.4	22.7	21.9	22.0	21.7	21.7	22.2	21.6
40582	A469	31.8	25.5	32.2	24.7	24.5	24.3	24.0	25.1	24.5	24.5
50651	A4119	28.4	22.9	31.6	24.5	23.5	23.9	23.8	24.0	25.1	24.6
40656	A4161	40.9	33.4	43.7	29.6	28.1	28.0	27.6	27.6	27.8	27.5
40549	A470	40.8	32.5	38.1	27.6	26.1	25.6	25.2	23.8	25.5	25.3
50527	A48	45.3	37.1	37.1	28.8	28.0	28.2	28.0	27.5	28.4	27.7

642	A4160	38.3	32.1	*40.0*	*28.8*	*27.8*	*30.0*	*29.8*	*27.4*	*28.2*	*28.6*
80899	A4232	43.1	34.3	*32.1*	*27.5*	*26.8*	*27.2*	*27.1*	*26.9*	*27.4*	*27.1*
99960	A4055	34.9	28.4	*31.4*	*25.5*	*24.0*	*24.1*	*24.1*	*24.0*	*24.8*	*24.4*
50541	A470	35.6	28.5	*37.3*	*29.1*	*28.3*	*28.2*	*28.0*	*27.1*	*28.2*	*27.8*
20548	A470	31.3	24.6	*41.3*	*30.0*	*27.9*	*27.8*	*27.3*	*23.8*	*25.9*	*27.1*
50524	A48	59.6	45.4	*36.4*	*27.9*	*27.6*	*27.6*	*27.5*	*27.1*	*27.7*	*26.9*
74101	A4232	52.5	40.7	*30.1*	*24.8*	*22.9*	*23.0*	*23.0*	*23.4*	*24.1*	*23.7*
638	A4119	27.5	21.6	*28.8*	*22.3*	*21.6*	*21.7*	*21.4*	*19.8*	*21.3*	*21.0*
30665	A4161	41.2	31.9	*55.7*	*41.1*	*37.3*	*36.0*	*35.0*	*31.9*	*32.5*	*35.3*
73233	A4055	35.8	29.1	*31.6*	*24.5*	*23.4*	*23.4*	*23.3*	*22.8*	*23.8*	*23.2*
99956	A4234	44.6	36.8	*38.2*	*26.3*	*25.4*	*26.3*	*26.2*	*26.6*	*26.1*	*26.2*
78439	A4232	33.6	26.4	*21.7*	*17.5*	*17.3*	*17.4*	*17.3*	*17.0*	*17.5*	*17.4*
70056	A4232	42.2	29.9	*35.3*	*28.9*	*29.6*	*29.8*	*29.7*	*27.5*	*30.1*	*29.5*
73232	A4160	26.9	21.2	*21.0*	*18.1*	*16.3*	*16.4*	*16.3*	*17.4*	*17.9*	*17.7*
80896	A470	26.5	22.2	*26.9*	*21.8*	*21.4*	*21.9*	*21.7*	*21.6*	*22.0*	*21.9*
80726	A470	35.4	25.3	*34.8*	*25.2*	*23.3*	*23.0*	*22.4*	*20.8*	*21.6*	*22.7*
78435	A4050	30.2	23.1	*32.5*	*25.0*	*24.1*	*24.3*	*24.2*	*24.2*	*25.0*	*24.7*

Note: local results are colour coded as green for less than 35µgm^{-3}, amber between 35µgm^{-3} and 40 µgm^{-3} and red for greater than 40µgm^{-3} (the compliance threshold). Numbers are rounded to the nearest integer, hence any values less than 40.5 µgm^{-3} are not counted as exceedances.

Figure 20: PCM links colour coded with CAZ 1 results in 2021

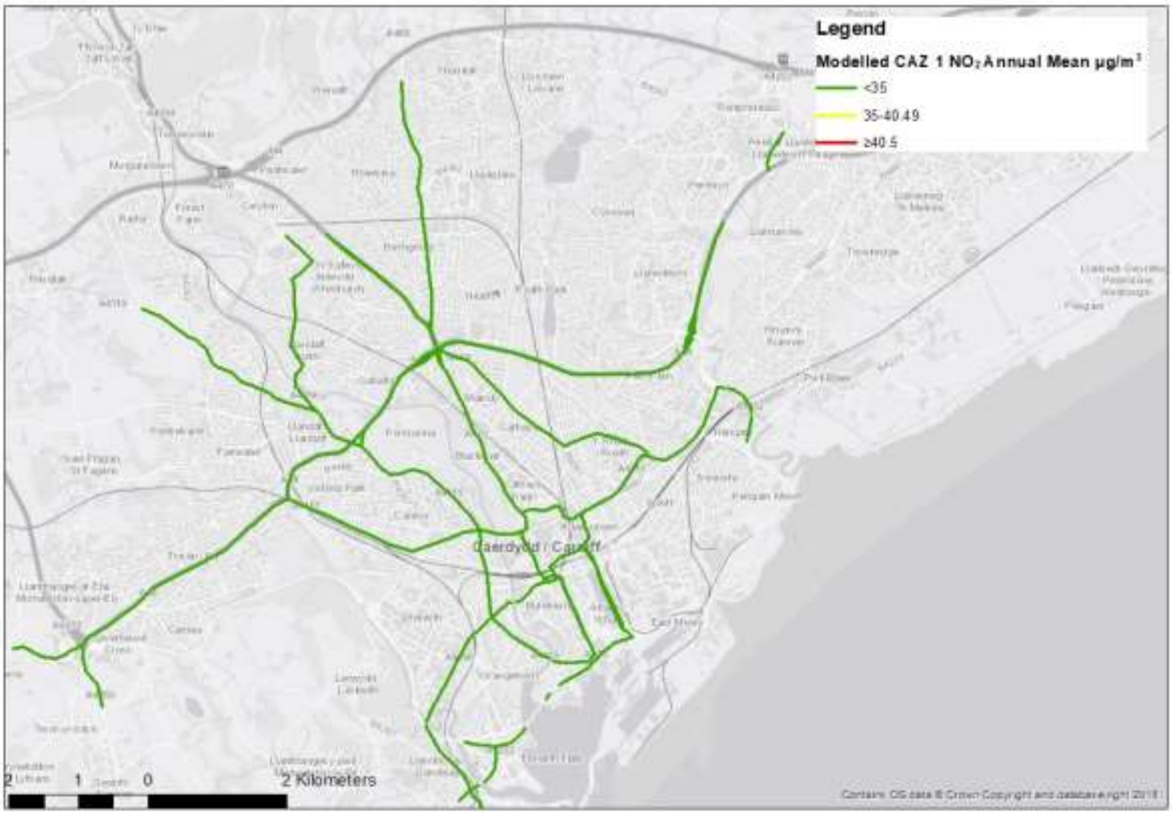


Figure 21 PCM links colour coded with CAZ 2 results for 2021

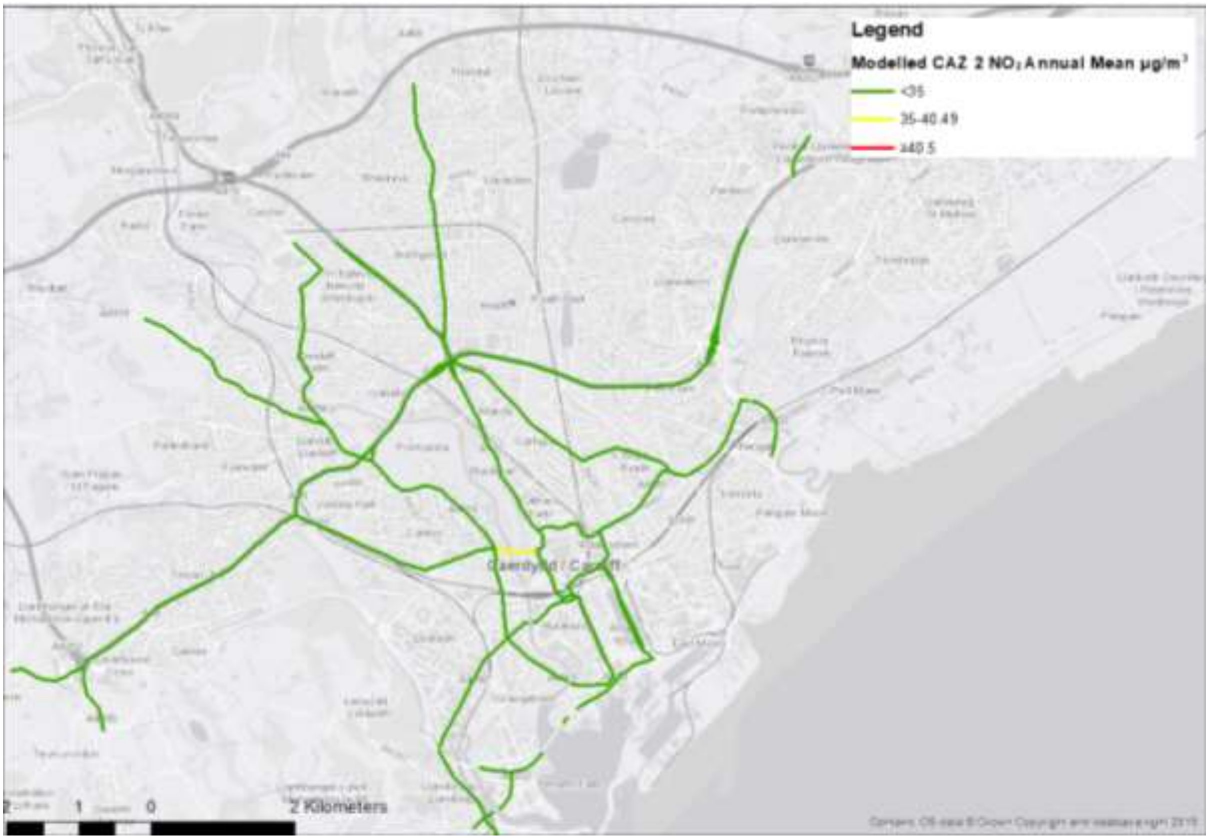


Figure 22 Sampled NO_2 results along the PCM links >35 µgm-3 for CAZ 2 results in 2021

4.4 Results for AQMAs and local exceedances

As with the baseline assessment modelled NO_2 annual mean concentrations have also been extracted from the model for each of the monitoring locations in Cardiff. Since these have been sited to capture the 'worst case' exceedance locations on local roads if the options are not showing any exceedance issues here it is unlikely that any problems are being generated on non-PCM roads. Similarly, as these are 'worst case' locations, they generally don't meet Air Quality Directive siting criteria (at AQD locations concentrations would be lower) therefore this is strong evidence that no new AQD exceedances would be generated by the preferred option.

Modelled NO_2 concentrations for all the scenarios have been calculated for each of the monitoring locations using the global adjustment factor and are shown in Table 18 below. The baseline 2021 data has been provided for reference.

These results provide an indication of whether compliance is predicted at monitoring locations in 2021. The majority of scenarios show compliance with the 40 µg/m^3 limit value for all sites by 2021, with the exception of baseline 2021. This shows exceedances of the 40 µg/m^3 limit at DT176 and DT186 both of which are on Castle Street and so in line with the results for the PCM links which sown Castle Street as an exceedance location.

Table 18: Predicted NO_2 annual mean concentrations at monitoring site locations in 2021 using the global adjustment factor

Monitoring site name	Site ID	Site type	2021 NO2 annual mean (µg.m-3)						
			Baseline	CASAP 1	CASAP 2	CASAP 3	CAZ 1	CAZ 2	Preferred CASAP
Ninian Park Road	16	Roadside	14.2	14	14.4	14.3	13.9	13.8	13.7
Mitre Place	33	Kerbside	31.5	29.9	29.8	29	30.3	29.9	28.5
City Road	44	Kerbside	20.4	19.8	19.8	19.7	19.7	19.9	19.6
Mackintosh Place	45	Kerbside	23.4	23.2	23	22.8	23.1	23.2	23.8
Penarth Road	49	Roadside	17.1	16.6	16.6	16.5	16.5	16.6	15.9
Birchgrove Village	56	Roadside	17.1	16.6	16.5	16.3	16.7	16.5	15.9
Westgate Street	58	Kerbside	30.3	24.9	26.3	25	24.5	25.2	22.4
Stephenson Court	81	Roadside	25.3	24.3	24.1	23.8	24.1	24.3	23.5
104 Birchgrove Road	82	Roadside	18	17.5	17.5	17.1	17.5	17.4	16.5
497 Cowbridge Road West	85	Roadside	15.2	14.6	14.6	14.4	15	14.7	14.4
19 Fairoak Road	86	Roadside	19	18.7	18.7	18.7	18.8	18.9	18.6
Manor Way Junction	96	Roadside	23.2	22.5	22.4	22	22.2	21.9	20.9
Newport Road (premises)	97	Roadside	21.4	20.8	20.8	20.6	20.8	20.4	20.4
Western Avenue (premises)	98	Roadside	18.2	17.6	17.7	17.5	17.8	17.8	17.4

Cardiff Road Llandaff	99	Roadside	27.8	26.3	26.3	25.6	26.7	26.5	25.2
Cardiff AURN	101	Urban Centre	18.4	17.7	17.5	17.3	17.2	17.6	16.8
Cardiff AURN	102	Urban Centre	18.4	17.7	17.5	17.3	17.2	17.6	16.8
Cardiff AURN	103	Urban Centre	18.4	17.7	17.5	17.3	17.2	17.6	16.8
30 Caerphilly Road	106	Roadside	24.6	23.7	23.6	23.4	23.6	23.4	22.3
Lynx Hotel	107	Roadside	21.6	21.1	21	20.9	21.1	20.9	20.7
98 Leckwith Road	111	Roadside	15.3	14.8	14.9	14.8	15.1	15	14.5
17 Sloper Road	112	Roadside	17.2	16.8	17.2	17.1	17	16.8	16.5
21 Llandaff Road	115	Roadside	15.2	14.9	14.9	14.8	15	15	14.4
25 Cowbridge Road West	117	Roadside	20	19.2	19.2	18.8	19.2	18.7	18.4
Havelock Street	119	Kerbside	22.3	20.6	20	19.2	20.6	21.1	19.3
287 Cowbridge Road East	124	Roadside	14.4	14.3	14.3	14.1	14.2	14.2	13.5
Westgate Street Flats	126	Roadside	27.6	23	24.1	23.1	22.7	23.3	20.9
117 Tudor Street	128	Roadside	16.1	15.8	16.9	16.7	15.7	15.7	15.6
Stephenson Court 2	129	Roadside	23.9	23	22.9	22.6	22.8	23	22.5
Burgess Court	130	Roadside	24.5	23.5	23.4	23.1	23.3	23.5	23
Dragon Court	131	Roadside	24.7	23.7	23.6	23.3	23.5	23.7	23.1

St Mark's Avenue	133	Roadside	28.1	27	27	26.8	27.7	26.9	25.9
Sandringham Hotel	134	Roadside	18.8	17.8	16.9	16.6	17.7	18	16.8
Lower Cathedral Road	139	Kerbside	19.8	19	20.8	20.6	18.8	18.3	17.7
Clare Street	140	Kerbside	21.2	20.4	22.3	22.1	20.5	19.9	19.2
Fairoak Road 2	141	Roadside	18.9	18.4	18.4	18.4	18.5	18.4	17.8
Windsor House	143	Roadside	27.9	22.9	24.5	23.3	23	23.5	20.9
Marlborough House	144	Roadside	26.6	22.4	21.7	20.8	22.4	23.2	20.3
Tudor Street Flats	145	Roadside	24.3	23.7	27.3	26.3	23.9	24.1	22.1
Neville Street	146	Roadside	19.8	18.9	19.4	19.1	19	18.7	18.2
211 Penarth Road	147	Roadside	17.5	17	16.7	16.6	16.9	16.7	16
161 Clare Road	148	Roadside	18	17.4	17.6	17.5	17.3	17.3	16.8
10 Corporation Road	149	Roadside	16.5	16.1	16.1	16	16.1	16.1	15.5
James Street	152	Roadside	22	21.4	21.7	21.6	22	21.8	21.6
Magic Roundabout	153	Roadside	21.6	21.3	21.4	21.3	21.5	21.5	21.1
2a/4 Colum Road	156	Roadside	18.5	18	17.9	17.7	18.2	18	17.6
47 Birchgrove Road	157	Roadside	20.8	20.2	20.2	19.9	20.2	19.9	19.3
64/66 Cathays Terrace	158	Roadside	18	17.5	17.5	17.4	17.4	17.5	16.8
IMO façade replacement	159	Roadside	22.6	22	21.9	21.7	22	21.5	21.7

High Street Zizzi	160	Urban Centre	20.6	19.1	18.9	18.5	18.4	19	17.7
52 Bridge Road	161	Roadside	18.9	18.2	18.2	17.8	18.4	18.2	17.4
58 Cardiff Road	162	Roadside	18	17.3	17.3	16.9	17.5	17.2	16.6
118 Cardiff Road	163	Roadside	19.4	18.7	18.8	18.7	19.3	18.7	18.6
725 Newport Road	164	Roadside	16.6	16.2	16.2	16.1	16.3	16.1	15.6
6 Heol Tyrrell	165	Roadside	13.2	12.8	12.8	12.8	13	12.9	12.8
163 Lansdowne Road	166	Roadside	16.9	16.5	16.5	16.4	16.4	16.5	16.2
359 Lansdowne Road	167	Roadside	17	16.5	16.5	16.2	16.4	16.4	16
570 Cowbridge Road East	168	Roadside	18.7	18.1	18.1	17.8	18.1	18.1	17.5
11 Pengam Green	170	Roadside	17.6	17.4	17.4	17.3	17.5	17.8	17.8
23 Tweedsmuir Road	171	Roadside	17.9	17.7	17.8	17.7	17.8	18.1	18.1
Ocean Way 1	172	Roadside	18.9	18.7	18.9	18.9	18.9	19	18.5
Ocean Way 2	173	Roadside	19.6	19.4	19.6	19.5	19.6	19.7	19.2
76 North Road	174	Kerbside	23.9	22.6	22.2	21.9	22.1	21.9	20.1
Castle Arcade	176	Roadside	42.7	38.8	37.5	36.4	32.9	37.1	33.3
Angel Hotel	177	Roadside	33.1	28	28.4	27.3	26.4	27.7	24.9
Park Street/Westgate Street	178	Kerbside	32	28.4	27.3	24.5	29	31.2	24.4

New sites added after 2015									
Altolusso, Bute Terrace	179	Roadside	26.3	24.6	23.9	23.6	24.5	24	23.5
Station Terrace	183	Kerbside	32.1	29.6	25.3	24.6	29.2	29.4	23.6
Hophouse, St Mary Street	184	Roadside	29.3	26.5	25.5	24.2	27.3	27.6	23.3
Northgate House, Duke Street	185	Roadside	27.2	25.2	25.2	24.5	23.2	24.9	22.3
Dempsey's Public House, Castle Street	186	Roadside	40.5	36.6	35.4	34.4	31.4	34.7	31.5
Angel Hotel	187	Roadside	32.8	27.6	28.1	26.9	26.1	27.1	24.4
Westgate Street (45 Apartments)	188	Roadside	35.1	30.5	28.3	25.4	30.7	31.8	28.3
3 Pearson Street	190		16.5	16.2	16.2	16.1	16.1	16.2	16
7 Mackintosh Place	191		23.7	23.4	23.3	23	23.4	23.5	24
3 Cowbridge Road West	192		18.8	18	18	17.7	18	17.7	17.4
24 Kings Road	193		20.1	20	20.4	20.3	20.5	20.3	21.9
115 Cowbridge Road West	194		16.6	16	16	15.8	16	15.7	15.6
244 Newport Road	195		24.8	24.1	24	23.8	24.1	23.6	23.6
2 Pencisely Road	196		18.1	17.4	17.5	17.4	18	17.9	17.4
GFF 369 Newport Road	197		20.1	19.7	19.7	19.6	19.7	19.6	19.5

Next Building to Stephenson Court	198		20	19.5	19.4	19.3	19.4	19.5	19.2
157 Newport Road	199		20	19.5	19.4	19.3	19.4	19.5	19.2
350 Whitchurch Road	200		25.7	24.7	24.7	24.5	25.3	24.9	24.1
23 Lower Cathedral Road	201		18.4	17.8	19.1	18.9	17.5	17.3	16.8
22 Clare Street	202		19.6	18.9	20.4	20.2	18.9	18.7	18.1
10 Fairoak Road	203		16.3	15.8	15.8	15.7	15.8	15.7	15.4
53 Neville Street	204		16.8	16.2	16.6	16.4	16.1	16.1	15.7
Fitzalan Court, Newport Road	205		22.1	21.3	21.6	21.3	21.1	21.3	20.8
Windsor House, Windsor Lane	206		21.9	21	20.6	20.3	20.4	20.8	19.6
42 Waungron Road	207		15.6	15.3	15.3	15.1	15.4	14.9	14.5
2 Llantrisant Road	208		17.7	17.2	17.2	16.9	17.4	16.9	15.9
178 North Road	209		22.7	21.5	21.2	20.9	21.4	20.2	18.3
485 Caerphilly Road	210		19.6	19	19	18.7	19.2	18.7	17.2
19 Well Wood Close, Penylan	211		17.2	17.4	17.5	17.4	17.5	16.9	16.5
62 Bridge Road	212		22.9	22	21.9	21.3	22.2	21.3	19.6

5 Sensitivity analysis

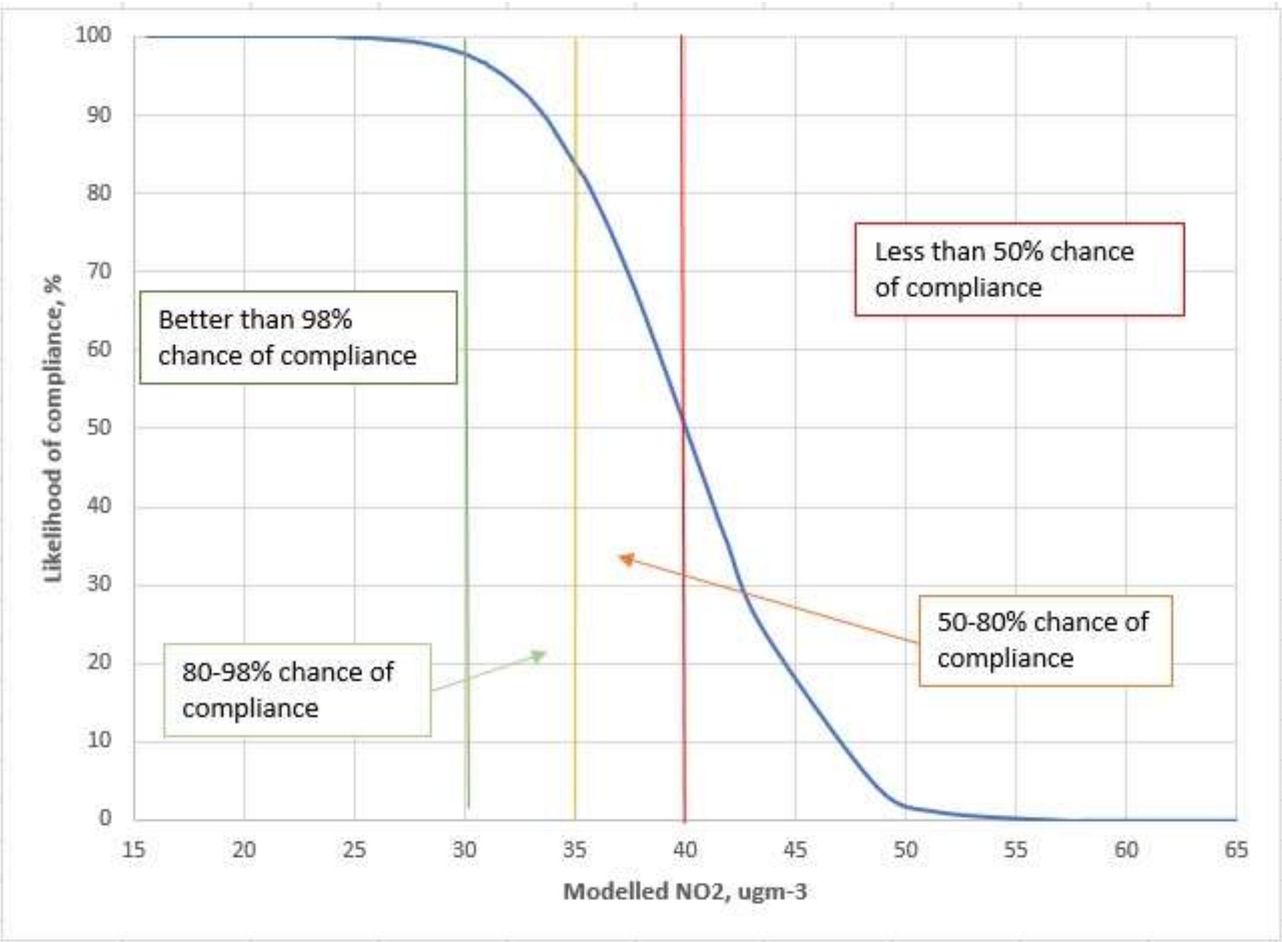
5.1 Model performance

Overall model performance is assessed both in the transport model and air quality model for the base year comparing modelled and measured data. Ultimately the combined level of model performance is assessed through verification of the air quality model against measured concentration data. In this process model performance and uncertainty is assessed using the Root Mean Square Error (RMSE) for the observed vs predicted NO_2 annual mean concentrations, as detailed in Technical Guidance LAQM.TG(16). In this case the RMSE was calculated at 5.1 µg.m^{-3} as described in section 3.4 and Appendix 1. This can then be used as a measure of uncertainty on forecast results for future years.

The RMSE can be used as a measure of uncertainty on forecast results for future years and to indicate likelihood of achieving a given result based on this level of model uncertainty, as illustrated in Figure 23. This shows that for a model with an RMSE of 5 µg.m^{-3} a modelled result of 35 µg.m^{-3} or less is required to have an 80% or better likelihood of compliance. This uncertainty metric has therefore been used when considering the results by identifying locations over 35 µg.m^{-3} as being at risk of exceedance.

The preferred CASAP scenario has been modelled to achieve 31.9 µg.m^{-3} which gives a 96% chance of achieving compliance given model error.

Figure 23 Probability distribution of compliance with an RMSE of 5 µg.m^{-3}



5.2 Results at monitoring locations using site-specific adjustment factors

When model verification is carried out this provides a clear indication of how the model is performing at each monitoring location. This can be used to provide an alternative set of results for the monitoring locations using a site-specific adjustment factor. The site-specific adjustment factor is simply derived from the ratio of measured and modelled road NOx at that specific site and used to adjust the predicted 2021 results rather than the global adjustment factor derived from model verification. The site-specific results aim to provide an indication of when compliance may be achieved at each monitoring site without any of the bias introduced by using an average road NOx adjustment factor across the entire domain.

The results at monitoring locations using the site-specific adjustment for the baseline and each of the modelled options are shown in Table 18. The results for the baseline indicate that in 2021, compliance with the 40 $\mu g.m^{-3}$ NO_2 annual mean objective will be achieved at all monitoring locations. This evidences the conservatism of dispersion modelling using global adjustment factor, which predicts an exceedance at monitoring location 176 Castle Arcade. This suggests that the dispersion model has a tendency to over-predict in areas with poor local air quality.

The site-specific factor requires a monitoring location to have a measured concentration in 2015, which is why monitoring locations introduced after 2015 have been removed. See Table 18 for modelled concentrations at all monitoring locations using the global adjustment factor.

Table 19 NO_2 concentrations at monitoring location in 2021 using the site-specific adjustment factor

Monitoring site name	Site ID	Site type	2021 NO2 annual mean (µg.m-3)						
			Baseline	CASAP 1	CASAP 2	CASAP 3	CAZ 1	CAZ 2	Preferred CASAP
Ninian Park Road	16	Roadside	20.4	19.8	20.9	20.6	19.6	19.4	19.1
Mitre Place	33	Kerbside	37.6	35.5	35.5	34.5	36	35.5	33.8
City Road	44	Kerbside	20.6	20	20	19.8	19.9	20.1	19.7
Mackintosh Place	45	Kerbside	24.6	24.4	24.3	24	24.4	24.5	25.1
Penarth Road	49	Roadside	23.3	22.2	22.2	22.1	22.1	22.2	20.8
Birchgrove Village	56	Roadside	23.1	22.1	22.1	21.6	22.3	22	21
Westgate Street	58	Kerbside	35	28.3	30.1	28.6	27.9	28.8	25.3
Stephenson Court	81	Roadside	24.6	23.6	23.4	23.2	23.4	23.6	22.9
104 Birchgrove Road	82	Roadside	18.3	17.8	17.8	17.4	17.8	17.7	16.8
497 Cowbridge Road West	85	Roadside	17.4	16.6	16.7	16.4	17.2	16.7	16.4
19 Fairoak Road	86	Roadside	27	26.5	26.7	26.6	26.8	26.9	26.4
Manor Way Junction	96	Roadside	23.7	22.9	22.8	22.4	22.6	22.3	21.2
Newport Road (premises)	97	Roadside	22.1	21.5	21.4	21.3	21.4	21.1	21
Western Avenue (premises)	98	Roadside	20.2	19.6	19.6	19.4	19.7	19.7	19.2

Cardiff Road Llandaff	99	Roadside	23.5	22.3	22.3	21.8	22.6	22.4	21.4
Cardiff AURN	101	Urban Centre	15.4	15.1	15	15	14.9	15.1	14.7
Cardiff AURN	102	Urban Centre	15.9	15.5	15.5	15.4	15.3	15.5	15.1
Cardiff AURN	103	Urban Centre	15.7	15.3	15.3	15.2	15.1	15.3	14.9
30 Caerphilly Road	106	Roadside	23.1	22.3	22.2	22	22.2	22	21
Lynx Hotel	107	Roadside	22.7	22.1	22.1	21.9	22.1	22	21.7
98 Leckwith Road	111	Roadside	16.6	16	16.1	16.1	16.4	16.2	15.6
17 Sloper Road	112	Roadside	21.3	20.7	21.3	21.2	21	20.7	20.3
21 Llandaff Road	115	Roadside	26.1	25	25.2	24.9	25.5	25.6	23.6
25 Cowbridge Road West	117	Roadside	29.9	28.4	28.4	27.8	28.4	27.6	27.1
Havelock Street	119	Kerbside	19.6	18.3	18	17.4	18.4	18.7	17.5
287 Cowbridge Road East	124	Roadside	17.2	16.9	17	16.6	16.9	16.8	15.6
Westgate Street Flats	126	Roadside	26.3	22	23.1	22.1	21.8	22.3	20.1
117 Tudor Street	128	Roadside	21.7	21.2	23.4	23	20.9	20.8	20.6
Stephenson Court 2	129	Roadside	22.2	21.4	21.3	21.1	21.2	21.4	21
Burgess Court	130	Roadside	24.4	23.5	23.3	23	23.2	23.5	23
Dragon Court	131	Roadside	27.1	25.9	25.7	25.4	25.6	25.9	25.1

St Mark's Avenue	133	Roadside	24.9	24	24	23.8	24.6	24	23.1
Sandringham Hotel	134	Roadside	22.2	20.5	19.2	18.7	20.4	20.8	19
Lower Cathedral Road	139	Kerbside	22.2	21.3	23.5	23.2	21	20.3	19.5
Clare Street	140	Kerbside	27.7	26.5	29.4	29.1	26.5	25.5	24.4
Fairoak Road 2	141	Roadside	25.5	24.6	24.7	24.6	24.8	24.4	23.4
Windsor House	143	Roadside	27.6	22.7	24.3	23.1	22.8	23.3	20.7
Marlborough House	144	Roadside	26	21.9	21.3	20.4	22	22.7	19.9
Tudor Street Flats	145	Roadside	20.8	20.5	23	22.3	20.6	20.7	19.3
Neville Street	146	Roadside	20.6	19.6	20.2	19.9	19.7	19.4	18.9
211 Penarth Road	147	Roadside	21.9	20.9	20.5	20.4	20.8	20.5	19.5
161 Clare Road	148	Roadside	21.9	20.9	21.3	21	20.8	20.8	20
10 Corporation Road	149	Roadside	26.5	25.2	25.3	25	25.2	25.2	23.7
James Street	152	Roadside	23.1	22.5	22.8	22.6	23.1	22.8	22.6
Magic Roundabout	153	Roadside	21.2	21	21	21	21.1	21.1	20.8
2a/4 Colum Road	156	Roadside	19.7	19.2	19	18.9	19.4	19.2	18.7
47 Birchgrove Road	157	Roadside	21.2	20.6	20.6	20.3	20.5	20.2	19.7
64/66 Cathays Terrace	158	Roadside	19.7	19.2	19.1	19	19.1	19.1	18.3
IMO façade replacement	159	Roadside	24.2	23.5	23.4	23.2	23.5	23	23.2

High Street Zizzi	160	Urban Centre	19.8	18.5	18.3	17.9	17.8	18.3	17.2
52 Bridge Road	161	Roadside	25.2	24.1	24.1	23.4	24.4	24	22.8
58 Cardiff Road	162	Roadside	19.4	18.6	18.5	18.1	18.8	18.5	17.7
118 Cardiff Road	163	Roadside	18.1	17.5	17.6	17.5	18	17.5	17.4
725 Newport Road	164	Roadside	16.1	15.7	15.7	15.7	15.8	15.7	15.2
6 Heol Tyrrell	165	Roadside	11.9	11.7	11.7	11.7	11.8	11.7	11.6
163 Lansdowne Road	166	Roadside	25.5	24.6	24.6	24.5	24.4	24.6	24
359 Lansdowne Road	167	Roadside	21.7	20.9	20.9	20.6	20.9	20.9	20.2
570 Cowbridge Road East	168	Roadside	18.7	18.1	18.1	17.8	18	18.1	17.5
11 Pengam Green	170	Roadside	15	14.9	14.9	14.8	14.9	15.1	15.1
23 Tweedsmuir Road	171	Roadside	15	15	15	15	15	15.1	15.1
Ocean Way 1	172	Roadside	24.4	24	24.5	24.5	24.4	24.6	23.6
Ocean Way 2	173	Roadside	19.2	19	19.2	19.2	19.2	19.3	18.9
76 North Road	174	Kerbside	20.9	19.8	19.6	19.3	19.5	19.3	17.9
Castle Arcade	176	Roadside	36.8	33.6	32.4	31.6	28.8	32.1	29
Angel Hotel	177	Roadside	35.6	29.9	30.4	29.2	28.1	29.7	26.5
Park Street/Westgate Street	178	Kerbside	27.8	24.8	24.1	21.9	25.4	27.1	21.8

5.3 Modelled sensitivity tests

This section provides the results the sensitivity analyses carried out on the transport and air quality modelling. Three key sets of tests were carried out:

- *Low performance of Euro 6 vehicles* – This test was carried out to assess the impact of Euro 6 light duty vehicles not performing as well as expected in terms of emissions performance. For this test all light duty Euro 6 vehicles were set to the base Euro 6a standard in the model. This test was carried out for the 2021 baseline scenario and preferred CASAP option.
- *Lower fNO_2 by 40%* - this test was carried out to consider the impact of lower fNO_2 as part of the NOx to NO_2 conversion process. This was done as new evidence is suggesting the fNO_2 may be lower than previously considered for newer vehicles. The test was to reduce fNO_2 by 40% for the NOx to NO_2 conversion process. This test has been carried out for the 2021 baseline and preferred CASAP option.
- *CASAP low test* – this test was used to assess the impact of more pessimistic assumptions in relation to the performance of the CASAP measures. The key assumptions where uncertainly was greatest and where a lower assumption was used were:
  - Uptake of the bus retrofit programme – this was reduced from 80% to 50%;
  - Zero uptake of the ULEV taxi grant;
  - A reduction in the mode shift impact of the active travel measures from 3% to 1%.

The results of the Euro 6 and fNO_2 tests are shown in Table 20 and Table 21 and the results of the CASAP low test are shown in Table 22. The results of these tests can be summarised as follows:

- Lower performance of Euro 6 – this test increased concentrations in the 2021 baseline by between 1.3 µg.m^{-3} and 3.3 µg.m^{-3} with an average 2 µg.m^{-3}. This increased the exceedance on Castle Street from 41.1 µg.m^{-3} to 44.4 µg.m^{-3} but did not generate any new exceedances. The impact of this test on the preferred CASAP option was to increase the concentration on Castle Street to a maximum of 35.2 µg.m^{-3} still well under the compliance limit value.
- Lower fNO_2 by 40% - this significantly reduces concentrations by between 1 µg.m^{-3} and 5 µg.m^{-3}. This removes the exceedance on Castle Street and only serves to improve the outcome of the preferred CASAP option.
- CASAP low test – this increased concentration from between 0 and 3 µg.m^{-3}, with the result on Castle Street increasing from 31.9 µg.m^{-3} to 34.6 µg.m^{-3}. If this test is combined with the worst-case impact of the Euro 6 test the result on Castle Street would increase to a maximum of 37.9 µg.m^{-3} so is still achieving the limit value.

This indicates that the preferred CASAP package is robust under the sensitivity tests carried out, in terms of its ability to achieve compliance.

Table 20: 2021 baseline sensitivity test results – Maximum predicted NO_2 annual mean on PCM links (Euro 6 emission standards test, and reduced fNO_2 ratios)

CensusID	Road Name	2021 NO_2 annual mean concentration (µg.m^{-3})				
		Baseline	Euro 6 test	% change Euro 6 test	fNO_2 40% reduction test	% change fNO_2 test
30660	A4119	30.7	33.2	8%	28.3	-8%
10629	A4054	19.5	20.9	7%	18.3	-6%
50647	A4119	24.4	26	7%	22.9	-6%
10660	A4161	26.2	28.1	7%	24.6	-6%

CensusID	Road Name	2021 NO_2 annual mean concentration ($\mu g.m^{-3}$)				
		Baseline	Euro 6 test	% change Euro 6 test	fNO_2 40% reduction test	% change fNO_2 test
522	A48	25.4	28.1	11%	23	-9%
30659	A4119	18.8	20.2	7%	17.8	-5%
77018	A470	30.6	33.1	8%	28.4	-7%
99955	A4160	26.9	28.9	7%	25.4	-6%
50660	A4161	30.8	33.2	8%	28.3	-8%
70055	A4161	30.4	32.8	8%	28.3	-7%
99671	A469	21.5	23.2	8%	20.1	-7%
10659	A4160	23.7	25.4	7%	22.4	-5%
10655	A4119	29	31.6	9%	26.3	-9%
80898	A4232	29.5	32.6	11%	26.8	-9%
20527	A48	30.6	33.6	10%	27.7	-9%
40655	A4160	19.3	20.6	7%	18.3	-5%
50580	A469	25.8	28.2	9%	23.7	-8%
50657	A4161	20.3	21.9	8%	19.1	-6%
10661	A4161	20.2	21.8	8%	19.1	-5%
10527	A48	22.7	24.4	7%	21.1	-7%
40582	A469	24.7	26.6	8%	23	-7%
50651	A4119	24.5	26.6	9%	22.6	-8%
40656	A4161	29.6	31.5	6%	27.7	-6%
40549	A470	27.6	29.9	8%	25.3	-8%
50527	A48	28.8	31.4	9%	26.1	-9%
642	A4160	28.8	30.8	7%	27	-6%
80899	A4232	27.5	29.8	8%	25.6	-7%
99960	A4055	25.5	27.8	9%	23.5	-8%
50541	A470	29.1	31.9	10%	26.4	-9%
20548	A470	30	32.1	7%	27.7	-8%
50524	A48	27.9	30.6	10%	25.3	-9%
74101	A4232	24.8	27	9%	22.9	-8%
638	A4119	22.3	23.8	7%	21.1	-5%
30665	A4161	41.1	44.4	8%	36.6	-11%
73233	A4055	24.5	26.6	9%	22.7	-7%
99956	A4234	26.3	28.1	7%	24.9	-5%
78439	A4232	17.5	18.9	8%	16.5	-6%
70056	A4232	28.9	31.8	10%	26.4	-9%
73232	A4160	18.1	19.8	9%	17.1	-6%
80896	A470	21.8	23.2	6%	20.8	-5%
80726	A470	25.2	26.7	6%	23.7	-6%
78435	A4050	25	27.5	10%	22.7	-9%

Table 21: 2021 Preferred CASAP option – Maximum predicted NO_2 annual mean on PCM links (Euro 6 emission standards test, and reduced fNO_2 ratios

CensusID	Road Name	2021 NO_2 annual mean concentration ($\mu g.m^{-3}$)				
		Baseline	Euro 6 test	% change Euro 6 test	fNO_2 40% reduction test	% change fNO_2 test
30660	A4119	30.1	32.6	8%	27.7	-8%
10629	A4054	17.7	19.1	8%	16.5	-7%
50647	A4119	22.2	23.8	7%	20.7	-7%
10660	A4161	25.4	27.3	7%	23.8	-6%
522	A48	24.4	27.1	11%	22	-10%
30659	A4119	17.6	19	8%	16.6	-6%
77018	A470	24.1	26.6	10%	21.9	-9%
99955	A4160	26.1	28.1	8%	24.6	-6%
50660	A4161	25.4	27.8	9%	22.9	-10%
70055	A4161	26.6	29	9%	24.5	-8%
99671	A469	20	21.7	9%	18.6	-7%
10659	A4160	21.4	23.1	8%	20.1	-6%
10655	A4119	26.3	28.9	10%	23.6	-10%
80898	A4232	28.6	31.7	11%	25.9	-9%
20527	A48	31.4	34.4	10%	28.5	-9%
40655	A4160	17.7	19	7%	16.7	-6%
50580	A469	24.2	26.6	10%	22.1	-9%
50657	A4161	19	20.6	8%	17.8	-6%
10661	A4161	18.8	20.4	9%	17.7	-6%
10527	A48	21.7	23.4	8%	20.1	-7%
40582	A469	25.1	27	8%	23.4	-7%
50651	A4119	24	26.1	9%	22.1	-8%
40656	A4161	27.6	29.5	7%	25.7	-7%
40549	A470	23.8	26.1	10%	21.5	-10%
50527	A48	27.5	30.1	9%	24.8	-10%
642	A4160	27.4	29.4	7%	25.6	-7%
80899	A4232	26.9	29.2	9%	25	-7%
99960	A4055	24	26.3	10%	22	-8%
50541	A470	27.1	29.9	10%	24.4	-10%
20548	A470	23.8	25.9	9%	21.5	-10%
50524	A48	27.1	29.8	10%	24.5	-10%
74101	A4232	23.4	25.6	9%	21.5	-8%
638	A4119	19.8	21.3	8%	18.6	-6%
30665	A4161	31.9	35.2	10%	27.4	-14%
73233	A4055	22.8	24.9	9%	21	-8%
99956	A4234	26.6	28.4	7%	25.2	-5%
78439	A4232	17	18.4	8%	16	-6%

CensusID	Road Name	2021 NO_2 annual mean concentration ($\mu g.m^{-3}$)				
		Baseline	Euro 6 test	% change Euro 6 test	fNO_2 40% reduction test	% change fNO_2 test
70056	A4232	27.5	30.4	11%	25	-9%
73232	A4160	17.4	19.1	10%	16.4	-6%
80896	A470	21.6	23	6%	20.6	-5%
80726	A470	20.8	22.3	7%	19.3	-7%
78435	A4050	24.2	26.7	10%	21.9	-10%

Table 22: 2021 Preferred Clean Air Strategy Action Plan (CASAP) Option – comparison of modelled NO_2 annual mean concentrations with core assumed positive feedbacks and low positive feedbacks

CensusID	Road Name	2021 NO_2 annual mean concentration ($\mu g.m^{-3}$)		
		Pref CASAP (Core)	Pref CASAP (Low)	% change in concentration
30660	A4119	30.1	29.6	-2%
10629	A4054	17.7	18.1	2%
50647	A4119	22.2	23.2	5%
10660	A4161	25.4	25.5	0%
522	A48	24.4	24.4	0%
30659	A4119	17.6	17.8	1%
77018	A470	24.1	27.2	13%
99955	A4160	26.1	26.3	1%
50660	A4161	25.4	26.6	5%
70055	A4161	26.6	26.9	1%
99671	A469	20	20.2	1%
10659	A4160	21.4	21.6	1%
10655	A4119	26.3	26.6	1%
80898	A4232	28.6	28.4	-1%
20527	A48	31.4	31.3	0%
40655	A4160	17.7	17.9	1%
50580	A469	24.2	24.3	0%
50657	A4161	19	19	0%
10661	A4161	18.8	18.6	-1%
10527	A48	21.7	21.7	0%
40582	A469	25.1	25.2	0%
50651	A4119	24	24.1	0%
40656	A4161	27.6	28.1	2%
40549	A470	23.8	23.9	0%
50527	A48	27.5	27.5	0%
642	A4160	27.4	27.3	0%
80899	A4232	26.9	26.7	-1%

CensusID	Road Name	2021 NO_2 annual mean concentration ($\mu g.m^{-3}$)		
		Pref CASAP (Core)	Pref CASAP (Low)	% change in concentration
99960	A4055	24	24	0%
50541	A470	27.1	27.2	0%
20548	A470	23.8	24.5	3%
50524	A48	27.1	27.2	0%
74101	A4232	23.4	23.3	0%
638	A4119	19.8	20.4	3%
30665	A4161	31.9	34.6	8%
73233	A4055	22.8	22.8	0%
99956	A4234	26.6	26.3	-1%
78439	A4232	17	17	0%
70056	A4232	27.5	27.5	0%
73232	A4160	17.4	17.3	-1%
80896	A470	21.6	21.5	0%
80726	A470	20.8	22	6%
78435	A4050	24.2	24.2	0%

5.4 Discussion of wider modelling sensitivities

Further potential areas of uncertainty in the modelling were set out in guidance provided by JAQU. These uncertainties are discussed in the following sections.

5.4.1 Zonal vs full model domain calibration

A single road NOx adjustment factor was derived from model verification and used to calculate:

- Citywide modelling results at receptor points adjacent to relevant PCM road links
- Citywide 1m resolution NO_2 annual mean concentration rasters providing a continuous representation of the spatial variation in modelled concentrations.

The use of a zonal model verification approach was also considered during our analysis of modelled vs measured road NOx; we concluded:

- There was no clear pattern in the value of road NOx adjustment factors across different zones of the city; allocating zones would therefore have been a subjective process.
- There could be various factors contributing to variable model agreement at individual measurement sites across the domain, these include uncertainties or omissions in the modelled traffic activity data, uncertainties in estimates of background concentrations, and omission of other nearby sources that have not been explicitly modelled e.g. bus stops, car parks etc. When modelling at the local scale, we typically model with a consistent background concentration across the model domain; and the impact of other sources such as car parks and bus stops can be modelled. Including this amount of detail is not however practical when modelling at city scale.
- Using a zonal approach could be considered relevant when the intention of the modelling is to focus on evidence relevant to specific areas or hotspots within the wider model domain e.g. small AQMAs. For these, applying a zone-specific road NOx adjustment factor may reduce the overall average error between measured and modelled concentrations at that location and hence increase confidence in the model results and associated conclusions. However, when generating evidence relevant to citywide impacts, applying different road NOx adjustment factors across the domain may create sudden step changes in modelled concentrations at the edge of each zone. It may also have led to inconsistencies in the modelled concentrations at receptor

points adjacent to relevant PCM road links where these were at the edge of a (subjectively allocated) verification zone.

- We have however presented results using road NOx adjustment factors specific to each monitoring site, as described in sections 3.2 and 4.2, which could be considered as a site specific zonal verification approach. This aims to provide an indication of when it is likely that compliance will be achieved at each measurement site even if the required road NOx adjustment factor is higher than the slope of the best fit line across all sites.

5.4.2 Background NO_2 calibration

JAQU's supplementary note on sensitivity testing suggests that some local authorities may have calibrated background concentrations by comparing Defra background maps with measured background concentrations in the local area. LAs then run a sensitivity test by removing the effects of calibration if background concentrations were calibrated in the 'central' modelling and applying a calibration if background concentrations were not calibrated in the 'central' modelling (but this may not be possible if no data is available for calibration).

In this case, this was not considered as an appropriate approach as no background NOx measurements were available to calibrate the modelled background.

5.4.3 f-NO_2 and calibration

The supplementary note suggests – '*If LAs have a number of roadside chemiluminescence monitors within their model domain they may wish to run a sensitivity test to examine the possible impact of this effect by calibrating for NOx using data from chemiluminescence monitors only (then calibrating for NO_2 using all monitoring sites)'*.
There were a limited number chemiluminescence monitors in Cardiff in 2015 that could have been used for such a calibration. We also consider that the use of a much more comprehensive set of diffusion results, although with greater uncertainty in the measured concentrations when compared with automatic analysers, gives a much more robust set of model agreement statistics.

5.4.4 Surface roughness length

The supplementary guidance states that *JAQU suggest that LAs model both high and low surface roughness sensitivity tests, scaling surface roughness by appropriate amounts (which will vary on a case by case basis)*.

And: '*As with other sensitivity tests the focus should be on the baseline and with measures projected year modelling, although in this case LAs should strongly consider also running the sensitivity in the base year. This is because the surface roughness length will impact on concentrations in the base year, therefore could impact on the calibration factors derived in the base year (and applied in the projected year)*.

As described in the modelling method report, we have modelled a uniform surface roughness across the entire domain representing a typical roughness for a large urban area. We would argue that changing the surface roughness modelled would require re-running and re-verification of the 2015 baseline model to derive a Road NOx adjustment (model calibration) factor that is specific to modelling with that roughness input parameter. To model like for like with the updated baseline, all future year scenarios would also need to be re-modelled and the results processed and re-presented.

We anticipate that this would not significantly change the future year modelled concentrations and hence conclusions of the assessment. The level of effort required to do this repeat modelling, combined with the current timescale pressures for delivery of the modelling evidence base, mean that exploring this sensitivity by re-modelling is not currently considered proportionate.

5.4.5 Meteorology

The sensitivity guidance contains some useful information regarding the potential for inter-annual variability in meteorological conditions to impact on modelled concentrations.

'*JAQU has attempted to quantify the potential for meteorologically driven inter-annual variability in NO_2 concentrations by investigating the impact of applying 3 different years of meteorological data from the same site (with all other inputs remaining constant) on NO_2 concentrations for a 'mock' LA. The study suggests (though results are not statistically meaningful given that only one 'mock' area has been considered with 3 years of meteorological data) that inter-annual changes in meteorology may not have a large impact on the overall distribution of roadside NO_2 concentrations in a local area but can have a significant impact for particular road links (as reflected in the considerably higher maximum concentration in 2015).'*

This statement suggests that alternative met years would not significantly affect the overall outcome of the analysis. We also note that to conduct a statistically robust sensitivity test of inter-annual variation in meteorological conditions would require modelling using multiple annual datasets. As it is critical to achieve compliance as quickly as possible, and timescales for submission of evidence have been agreed, we do not currently have enough time or resources to conduct this repeat modelling, therefore exploring this sensitivity in detail by re-modelling multiple times is not currently considered proportionate.

6 Conclusions

A detailed air quality modelling exercise has been carried out covering the whole of the Cardiff area to establish baseline levels of NO_2 concentrations and to assess the impact of a range of roadside NO_2 abatement packages. The mitigation packages covered:

- Three Clean Air Strategy and Action Plan (CASAP) scenarios – CASAP 1 to 3;
- Two Clean Air Zone scenarios – a city centre scheme targeting cars and one targeting HGVs;
- A final 'preferred' CASAP scenario – comprising the key elements of CASAP 1 to 3.

The results of the CASAP 1 to 3 package were reviewed by the Council and the project team, and from this the preferred CASAP package was defined. The analysis of the two CAZ options identified a car based scheme as providing the greatest benefit. This results in two options: the preferred CASAP and the car-based CAZ scheme being taken through to the final business.

This analysis indicates that the key compliance issue that remains to be solved in 2021 under the baseline scenario is on Castle Street. The two mitigation options that have been taken forward into the final business to solve this compliance issue perform as follows:

- *A preferred CASAP package* – the assessment indicates a significant improvement of NO_2 concentrations on Castle Street reducing NO_2 levels to a maximum of 31.9 $\mu g.m^{-3}$ which then comfortably achieves compliance. The average improvement across all PCM links is 2 $\mu g.m^{-3}$ with the maximum improvement being on Castle Street.
- *The city centre car-based (CAZ 1) charging scheme* –this option is also modelled to achieve compliance on Castle Street achieving a maximum concentration of 32.5 $\mu g.m^{-3}$. However, the overall impact of this scheme is less than the CASAP scenario with an average improvement across the PCM links of only 1 $\mu g.m^{-3}$ with some links showing an increase due to traffic diverting to avoid the scheme.

The sensitivity analysis carried out on the transport and air quality models indicated that the both the CASAP and CAZ 1 schemes were robust in achieving compliance even when the underlying assumptions were flexed.

Appendices

Appendix 1: Air quality model verification and adjustment

Appendix 1: Air quality model verification and adjustment

A.1.1 Verification and adjustment

Verification of the model involves comparison of the modelled results with any local monitoring data at relevant locations; this helps to identify how the model is performing and if any adjustments should be applied. The verification process involves checking and refining the model input data to try and reduce uncertainties and produce model outputs that are in better agreement with the monitoring results. This can be followed by adjustment of the modelled results if required. The LAQM.TG(16) guidance recommends making the adjustment to the road contribution of the pollutant only and not the background concentration these are combined with.

The approach outlined in LAQM.TG(16) section 7.508 – 7.534 has been used in this case. All roadside diffusion tube NO_2 measurement sites in Cardiff have been used for model verification. A single road NOx adjustment factor was derived and used to calculate:

- Citywide modelling results at receptor points adjacent to relevant PCM road links.
- Citywide 1m resolution NO_2 annual mean concentration rasters providing a continuous representation of the spatial variation in modelled concentrations.

It is appropriate to verify the performance of the RapidAir model in terms of primary pollutant emissions of nitrogen oxides (NOx = NO + NO_2). To verify the model, the predicted annual mean Road NOx concentrations were compared with concentrations measured at the various monitoring sites during 2015. The model output of Road NOx (the total NOx originating from road traffic) was compared with measured Road NOx, where the measured Road NOx contribution is calculated as the difference between the total NOx and the background NOx value. Total measured NOx for each diffusion tube was calculated from the measured NO_2 concentration using the latest version of the Defra NOx/NO_2 calculator (v6.1).

The initial comparison of the modelled vs measured Road NOx identified that the model was under-predicting the Road NOx contribution at most locations. Refinements were subsequently made to the model inputs to improve model performance where possible.

The gradient of the best fit line for the modelled Road NOx contribution vs. measured Road NOx contribution was then determined using linear regression and used as a domain wide Road NOx adjustment factor. This factor was then applied to the modelled Road NOx concentration at each discretely modelled receptor point to provide adjusted modelled Road NOx concentrations. A linear regression plot comparing modelled and monitored Road NOx concentrations before and after adjustment is presented in Figure 24.

The total annual mean NO_2 concentrations were then determined using the NOx/NO_2 calculator to combine background and adjusted road contribution concentrations.
Some clear outliers (n = 7) were apparent during the model verification process, whereby we were unable to refine the model inputs sufficiently to achieve acceptable model performance at these locations. These sites were excluded from the model verification. The reasons why acceptable model performance could not be achieved at these sites include:

- Sites located next to a large car park, bus stop, petrol station, or taxi rank that has not been explicitly modelled due to unknown activity data.

- No traffic model road link included where the NO_2 sampler is located, or not all road links included e.g. at a junction.

The RapidAir canyon allocator identified Westgate Street as a canyon, however including a canyon in this location leads to very scattered data in the model verification and the sites located in this canyon do not follow the general trends shown by the remainder of the monitoring locations. Consequently, the canyon in Westgate was manually removed which resulted in the relationship between measured and modelled concentrations at sites in this street following similar trends to the other verification sites, and reduced the error in the model predictions.

To present a conservative approach to adjusting future year predictions of road NOx concentrations, a primary NOx adjustment factor (PAdj) of 1.807 based on model verification using all of the 2015 NO_2 measurements was applied to all modelled Road NOx data prior to calculating an NO_2 annual mean.

A plot comparing modelled and monitored NO_2 concentrations before and after adjustment during 2015 is presented in Figure 25.

Figure 24 ***Comparison of modelled Road NO_x Vs Measured Road NO_x before and after adjustment***

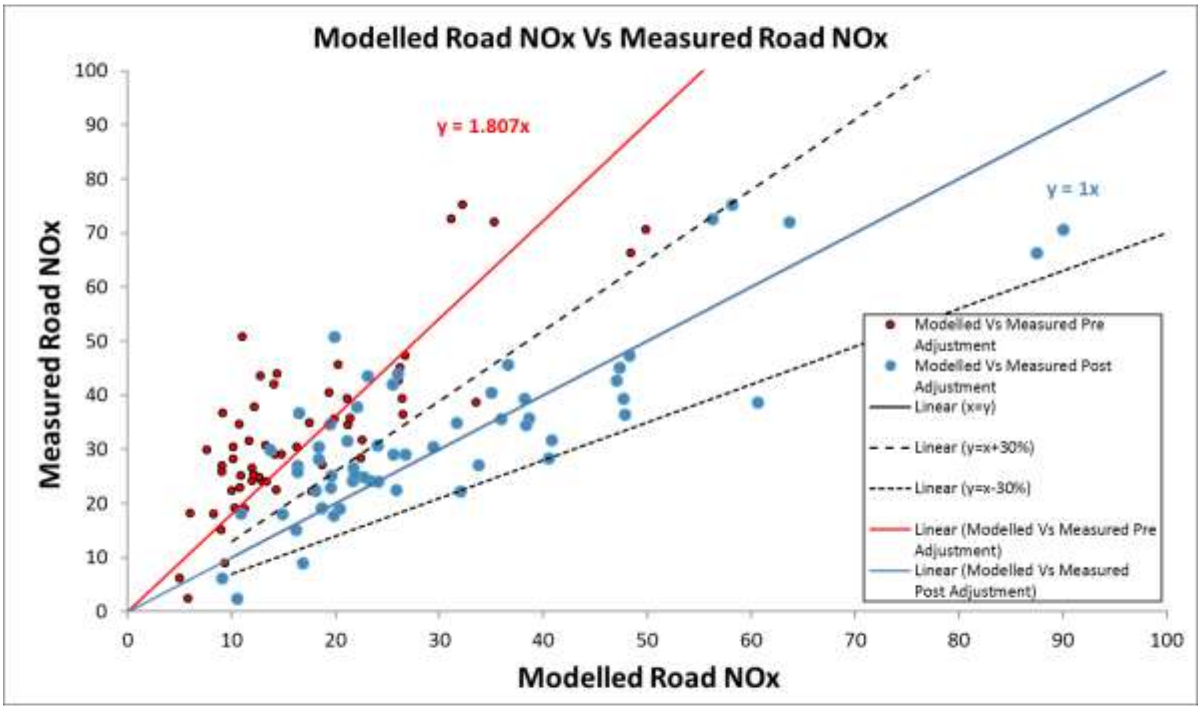
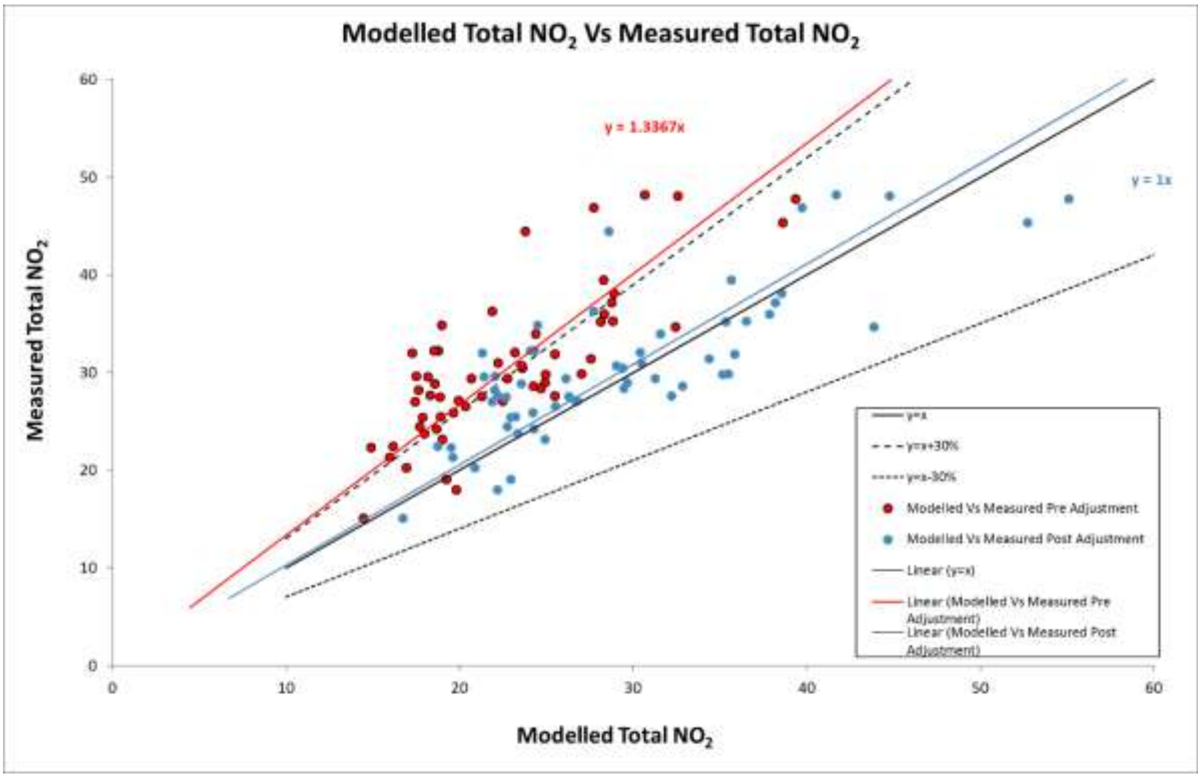


Figure 25 ***Modelled vs. measured NO_2 annual mean 2015 before and after adjustment***



A.1.2 Model performance

To evaluate the model performance and uncertainty, the Root Mean Square Error (RMSE) for the observed vs predicted NO_2 annual mean concentrations was calculated, as detailed in Technical Guidance LAQM.TG(16). This guidance indicates that an RMSE of up to 4 µg/m^3 is ideal, and an RMSE of up to 10 µg/m^3 is acceptable. The calculated RMSE is presented in Table A1. In this case the RMSE was calculated at 5.1 µg.m^{-3}which is close to the ideal range suggested by the guidance.

Table A1: Comparison of measured and modelled concentrations at measurement locations in 2015, and the model root mean square error.

NO_2 monitoring site	Measured NO_2 annual mean concentration 2015 (µg.m^{-3})	Modelled NO_2 annual mean concentration 2015 (µg.m^{-3})
DT33	46.9	39.7
DT44	27.1	26.8
DT45	32.1	30.4
DT56	29.6	22.0
DT58	48.3	41.7
DT81	35.3	36.5
DT82	23.8	23.4
DT85	22.4	19.5
DT86	34.9	24.5
DT96	31.1	30.5
DT97	30.5	29.4
DT98	25.4	22.9
DT99	29.8	35.2
DT100	28.9	23.5
DT106	29.4	31.3
DT107	30.7	29.0
DT111	21.3	19.6
DT112	27.1	21.9
DT119	27.7	32.2
DT124	22.5	18.7
DT126	36.0	37.9
DT128	29.6	21.4
DT129	31.5	34.4
DT130	35.2	35.3
DT131	39.5	35.6
DT133	31.9	35.8
DT139	29.4	26.1
DT140	36.3	27.7
DT141	32.3	24.1

NO_2 monitoring site	Measured NO_2 annual mean concentration 2015 ($\mu g.m^{-3}$)	Modelled NO_2 annual mean concentration 2015 ($\mu g.m^{-3}$)
DT143	38.2	38.6
DT144	37.2	38.2
DT145	29.9	35.5
DT146	26.6	25.5
DT147	27.7	22.2
DT148	27.5	22.7
DT152	27.6	26.3
DT153	29.0	29.7
DT156	25.9	24.2
DT157	27.2	26.7
DT158	25.5	23.2
DT159	34.0	31.6
DT161	32.3	24.3
DT162	24.5	22.7
DT163	23.2	24.9
DT164	20.3	20.9
DT165	15.1	16.7
DT166	32.1	21.3
DT167	28.3	22.0
DT168	24.3	24.3
DT170	19.1	23.0
DT171	18.1	22.2
DT172	44.5	28.6
DT173	28.4	29.5
DT175	34.7	43.9
DT174	28.7	32.8
DT176	47.8	43.9
DT177	48.1	55.1
DT178	45.4	44.8
	RMSE (all sites)	**5.1 $\mu g/m^3$**

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Cardiff Clean Air Zone – Air Quality Modelling Methodology Report

Report for City of Cardiff Council

ED 11182 | Issue Number 2 | Date 03/06/2019

Customer:

City of Cardiff Council

Customer reference:

City of Cardiff Council Feasibility Study

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Ricardo Energy & Environment reference:

Ref: ED11182- Issue Number 2

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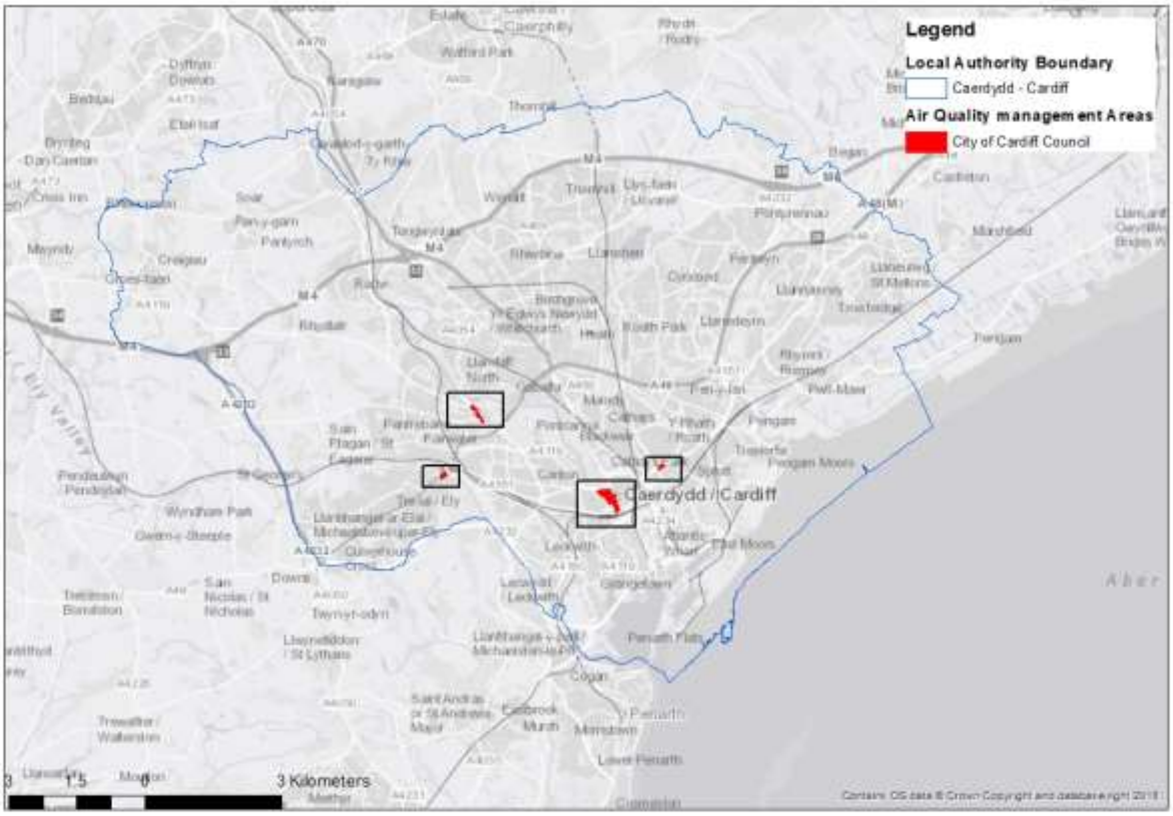
1 Introduction and outline modelling scope

City of Cardiff Council (CCC) has been directed by the Welsh Government to carry out a Nitrogen Dioxide Feasibility Study for non-compliance with the NO_2 limit values. This report sets out the Air Quality modelling methodology used for this study.

1.1 Background

Cardiff like many other urban areas, has elevated levels of Nitrogen Dioxide (NO_2) due mainly to road transport emissions. As such CCC has designated 4 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 Cardiff 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. In 2017 the UK government released a plan to tackle air quality, 'UK plan for tackling roadside nitrogen dioxide concentrations 2017'. Following a judicial review of this plan by Welsh ministers a Welsh Government Interim Supplemental Plan (WGSP) was published, identifying additional technical work to support measure development.

In WGSP, the areas of the pollution climate mapping (PCM) model which identify areas of exceedance in the Cardiff Urban Area are summarised as 'A4161','A4232', 'A4234', 'A470' and 'A48'. Additional areas identified as having poor air quality are established through the Local Air Quality Management (LAQM) regime. Yearly reviews in the form of annual status reports (ASR) review air quality within existing AQMAs. After reviewing Cardiff's latest ASR published in August 2018, Cardiff's

AQMAs cover the city centre, Ely bridge, Stephenson Court and Llandaff. Cardiff have been proactive in managing air quality prior to this NO_2 feasibility study and have proposed measures to improve air quality in these areas and more widely across the city in the Form of a Clean Air Strategy. Cardiff have also bid for funding for Ultra low emission buses/zero emission buses which will introduce electric buses within Cardiff's AQMAs and those areas identified within WGSP, such as the city centre AQMA, Stephenson Court AQMA and the A470 corridor.

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.

The current study has carried out a fully updated assessment of air quality in and around Cardiff in relation to European limit values for NO_2 using the latest data on emission factors and traffic activity. This assessment has been used to establish the extent of any air quality compliance issues in Cardiff and to assess the options needed to solve these compliance problems.

1.2 Outline scheme options

Cardiff's Clean Air Strategy Action Plan (CASAP) developed a package of measures to reduce emissions covering all key transport modes in the city: cars, freight, buses and taxis. This introduces a series of measures in three unique CASAP phases. This has been considered as an alternative to a charging clean air zone for achieving compliance with the NO_2 annual mean air quality directive in the shortest time possible. Two variations of charging clean air zones were also considered in this study, CAZ 1 where charges apply to private cars and CAZ 2 where charges apply to light goods vehicles (LGVs) and heavy goods vehicles (HGVs).

The measures included in air quality modelling of these options has been presented within Table 1. The measures which have been reflected in the transport modelling are noted in Table 1, the transport modelling methodology report[1] should be referenced for further information. As a general rule, certain measures can only be reflected in a traffic model which is why the detail of these measures are not included in air quality modelling. The effect of measures in the traffic model are demonstrated through emission calculations related to changes to traffic flow, composition and speed. The exception to this is CAZ 1 and 2, where the change in fleet mix, for example split between petrol/diesel vehicles were developed by the air quality team. Whereas the change in compliant and non-compliant traffic[2] flows associated with the CAZ is established by the traffic model.

Table 1 Outline of measures included in the traffic and air quality modelling exercises

Scenario	Measures reflected in air quality modelling	Measures reflected in traffic modelling
CASAP 1	1. Taxi Licensing, Euro 6 for new licensees and upgrade incentives; 2. Electric Buses on service routes 27, 49/50 and 44/45.	1. Active Travel Package; 2. Cycling Programme to end of 2020; and 3. 50 mph on A4232.
CASAP 2	1. All CASAP 1 measures.	1. All CASAP 1 measures plus

[1] 367590 Air Quality Transport Modelling Technical Note CASAP CAZ.pdf

[2] Compliant vehicles are those that meet the CAZ standard and non-compliant vehicles are those that do not. The CAZ standard is Euro VI for heavy duty vehicles and Euro 6 (diesel and Euro 4 (petrol) for light duty vehicles.

		2. Westgate Street Scheme; 3. East Side Scheme; 4. A48 Park and Ride; 5. J33 Park and Ride; and 6. Parking charges and controls.
CASAP 3	1. All CASAP 1 measures plus; 2. Complete upgrade of Cardiff Bus's fleet to Euro VI.	1. All CASAP 1 and 2 measures plus; 2. A470 additional southbound traffic lane; and 3. Nantgarw bus Park and Ride.
CAZ 1	1. **<u>No</u>** CASAP measures included; 2. £10 charge for private cars entering city centre charging clean air zone.	1. **<u>No</u>** CASAP measures included; and 2. £10 charge for private cars entering charging city centre charging clean air zone.
CAZ 2	1. No CASAP or CAZ 1 measures included; 2. £50 charge for heavy duty vehicles entering charging clean air zone. 3. £10 charge for light goods vehicles entering city centre charging clean air zone.	1. <u>No</u> CASAP or CAZ 1 measures included; 2. £50 charge for heavy duty vehicles entering charging clean air zone. 3. £10 charge for light goods vehicles entering city centre charging clean air zone.
Preferred CASAP	1. Taxi Licensing, Euro 6 for new licensees and ULEV upgrade incentives; 2. Electric Buses on service routes 27, 49/50 and 44/45. 3. Bus retrofit programme, assuming 80% uptake	1. Active travel package of 20mph zones and CS1 cycle scheme 2. City centre package comprising Castle street measures, Westgate scheme and Eastside scheme.

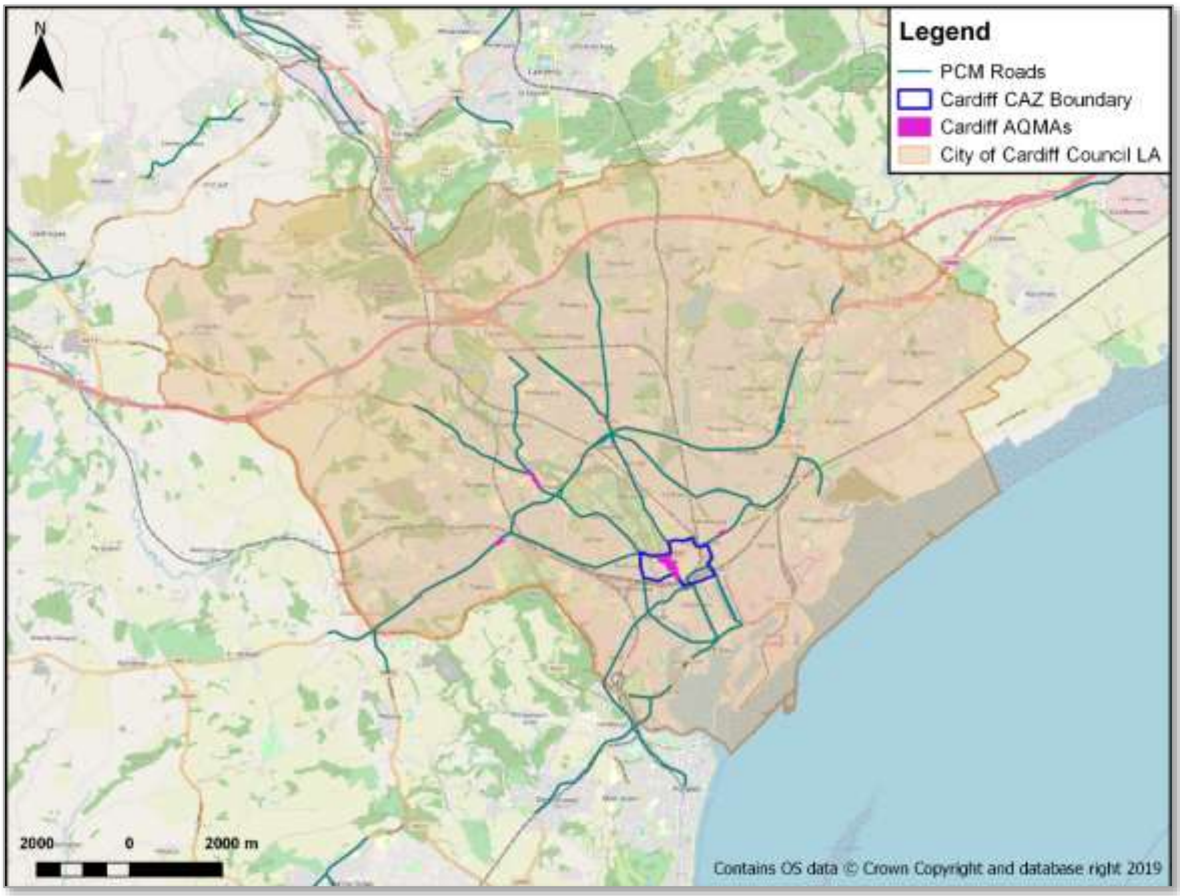
1.3 Modelling domain and years

Modelling measure options and associated air quality impacts requires a model domain that covers the scheme options, relevant AQMAs and potential diversion routes. Therefore, the model domain shown in Figure 2 has been used to cover the following:

- All the AQMAs in Cardiff including the main areas of concern from the national modelling assessment along the A470 and A48;
- The wider transport network out to and including the M4 which will cover all the likely key diversion routes should vehicles seek to avoid any Clean Air Zone

- The study area includes roads within 2km from the City of Cardiff's local authority boundary, thereby capturing the majority of roads outside Cardiff's jurisdiction which contribute towards local air quality within Cardiff.

Figure 2 Model domain



Two key model years are used in the modelling work: a 2015 base year and a target implementation year for the CAZ of 2021. The base year is taken as 2015 as this is the base year for the most recently validated transport model covering the area. To compliment this, the 2015 air quality data has been used to validate the air quality model. 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.
2016-2020	**Interim years** – interpolated between the base and implementation year.
2021	**Implementation year** – latest date when CAZ scheme is due to be in place.

1.4 Background modelling

The primary cause of air pollution problems in Cardiff is related to traffic activity and the impact of the any measures will target this traffic activity. As such the focus of the modelling is the transport emissions. Background pollutant concentrations can be taken from Defra's background maps which includes contributions from the majority of potential emissions sources e.g. other road traffic, industrial combustion and domestic emissions. With increasing distance from these emission sources Defra's background maps represent these emission sources relatively well. However, within close proximity to these emission sources Defra's Background maps can under-represent emissions.

To ensure a realistic representation of background pollutant concentrations, Part A(2) and B emissions to air processes permitted through the environmental permitting regime were reviewed. The outcome of this review is that the distance of industrial sources is such that they will be satisfactorily represented within Defra's background maps. Further information is provided in section 4.4.

Defra's background maps are based upon the same methodology as the PCM model[3]. These are based upon simplifications of emission sources from various sectors such as industry, the meteorological conditions and dispersion environment which cause pollutant concentrations. As Defra's guidance note on background concentrations states, these are estimates, to gauge how accurately these estimates represent background concentrations a comparison can be made against background monitoring locations. There is one background continuous analysers and two diffusion tube locations which can be compared against the estimated background concentrations, this comparison can be seen in Table 3. This shows that Defra's background estimates are actually higher than measured concentrations and use of these are slightly conservative.

Table 3 Comparison of Defra's modelled background concentration with measured

ID	Site Type	2015 Measured NO2 (µg/m3)	2015 Measured NO2 Data Capture %	2015 Defra Background modelled NO2 (µg/m3)	% difference between measured and monitoring
CA_1	Urban Centre	27	80	27.4	1%
169	Urban Background	16.3	100	18.4	13%
160	Urban Centre	27	92	27.4	1%

2 Details of the Modelling Domain

The core air quality model domain encompasses an area within 2km of the City of Cardiff's local authority boundary, based upon the district boundary from Ordnance Survey mapping products[4]. There is no significant displacement of traffic flows outside this domain due to the implementation of either charging CAZ – with a maximum increase of 70 AADT occurring on the A4160 (Penarth Road) with CAZ 1, in a maximum of a 170 AADT increase outside of Cardiff for CAZ 2 and so no material impacts are expected to occur beyond the proposed model domain.

A map showing the extent of the air quality domain relative to the initial CAZ zones and the associated traffic model network is presented in Figure 3. A map showing the model domain relative to roads included in the national Pollution Climate Mapping (PCM) model is presented in Figure 4. All road links in the PCM model pertinent to Cardiff are included in the model domain specification.

CCC has declared 4 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 5. All of CCC's 2015 NO_2 roadside measurements have been used in the air quality modelling assessment

[3] https://laqm.defra.gov.uk/documents/2015-based-background-maps-user-guide-v1.0.pdf

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

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 are measured by CCC is presented in Figure 6.

Figure 3: CAZ study domain and relationship to Mott Macdonald's sub-regional transport model links

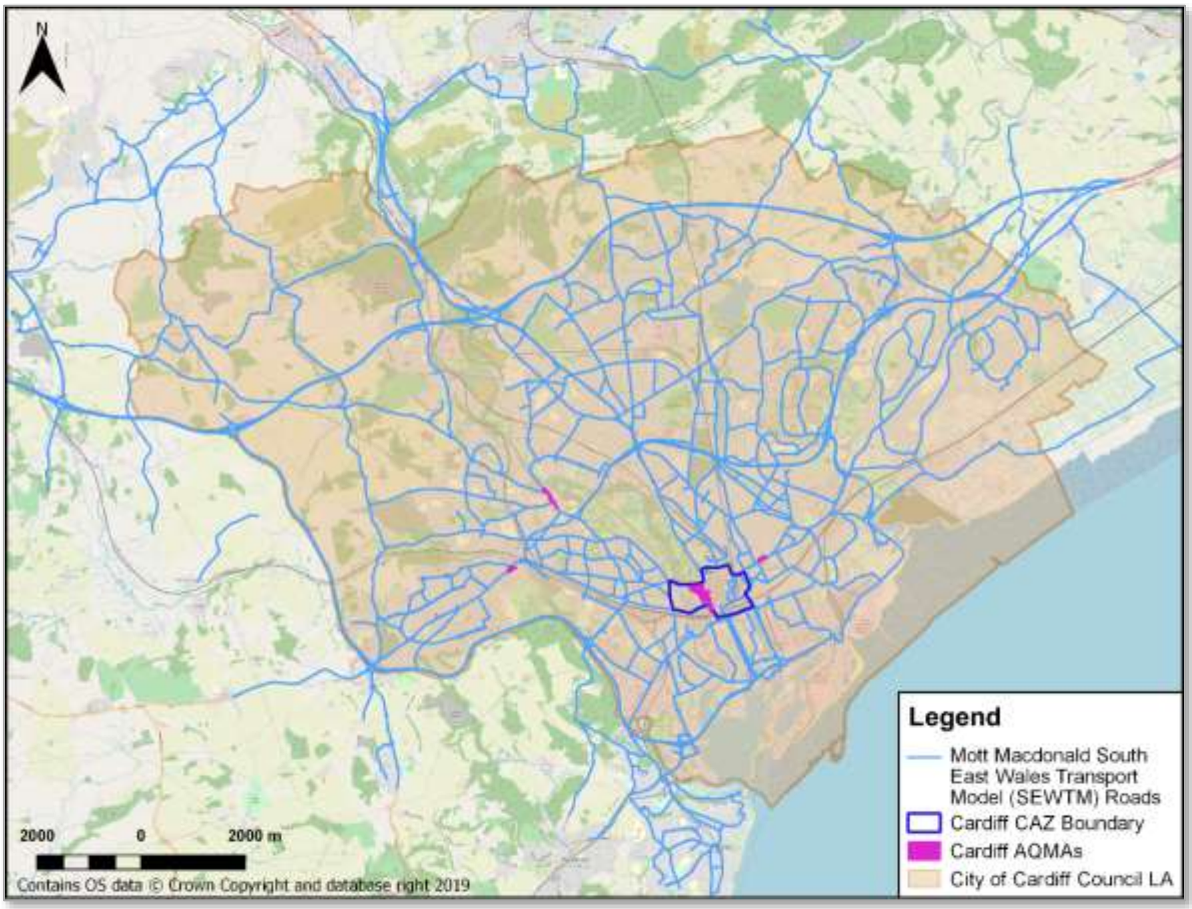


Figure 4: PCM model road links within the CAZ study domain 2015

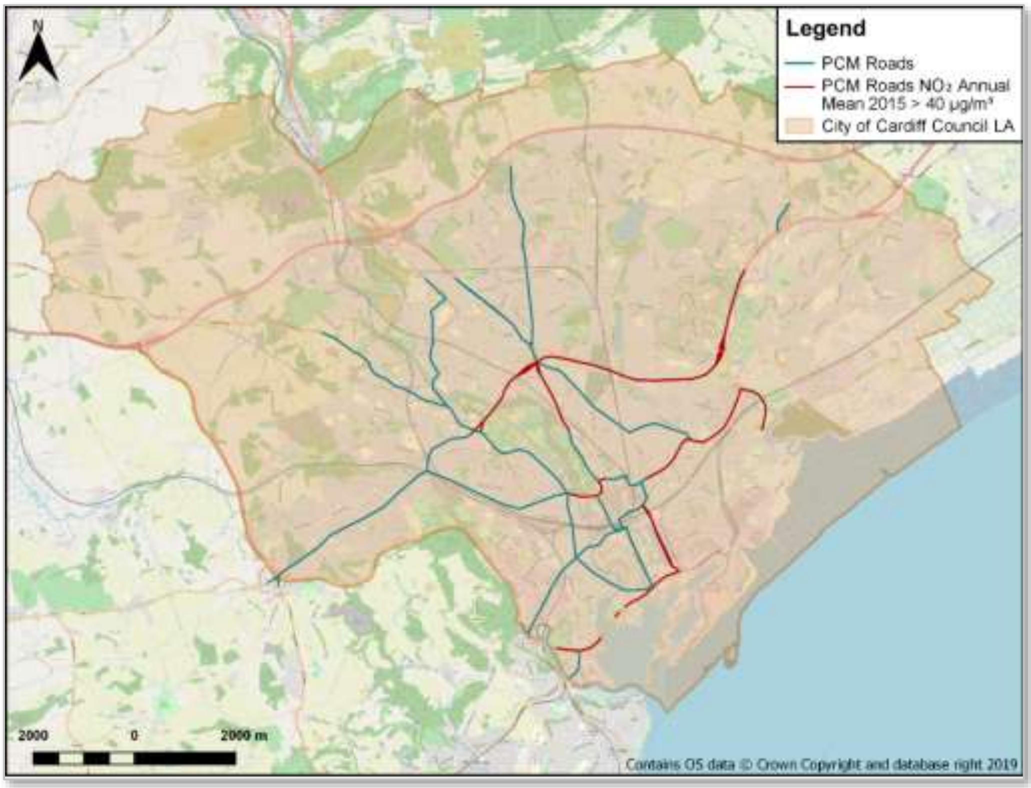


Figure 5: City of Cardiff Council's AQMA locations

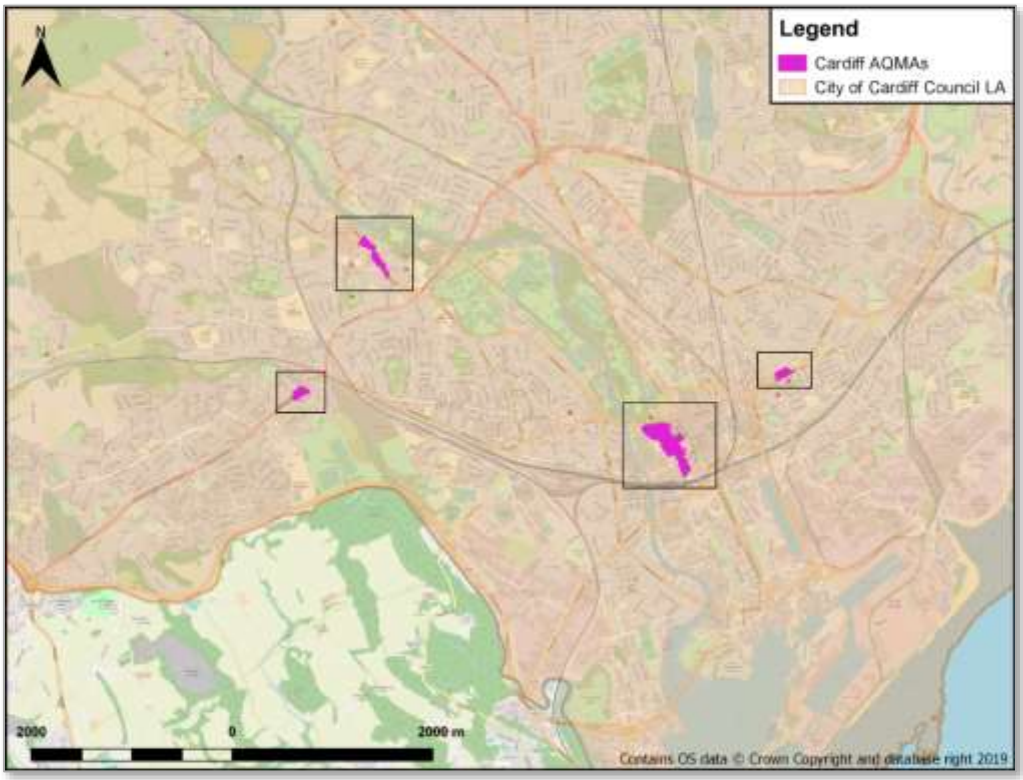
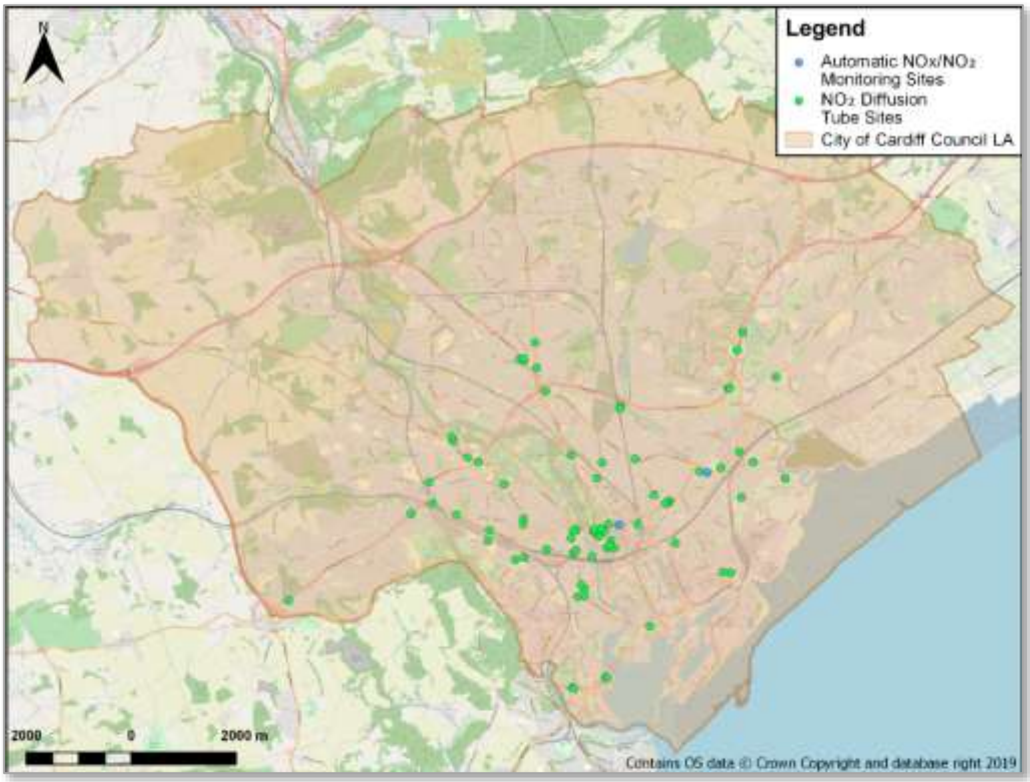


Figure 6 City of Cardiff Council's NO_2 monitoring sites



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 in other Clean Air Zone feasibility studies such as Derby, London and Southampton.

The model is based on convolution of an emissions grid with dispersion kernels derived from the USEPA AERMOD[5] model. The physical parameterisation (release height, initial plume depth and area source configuration) closely follows guidance provided by the USEPA in their statutory road transport dispersion modelling guidance[6]. 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[7]. The RapidAir model

[5] https://www3.epa.gov/ttn/scram/dispersion_prefrec.htm#aermod
[6] https://www.epa.gov/state-and-local-transportation/project-level-conformity-and-hot-spot-analyses
[7] 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

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[8]. 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. The results of this study have been published in Environmental Modelling and Software[9].

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 Cardiff City Centre. 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[10].

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

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[11,12]. The STREET model has been used for many years and has been adopted in dispersion modelling software

[8] https://uk-air.defra.gov.uk/research/air-quality-modelling?view=intercomparison
[9] Masey, Nicola, Scott Hamilton, and Iain J. Beverland. "Development and evaluation of the RapidAir® dispersion model, including the use of geospatial surrogates to represent street canyon effects." *Environmental Modelling & Software* (2018). DOI: https://doi.org/10.1016/j.envsoft.2018.05.014
[10] EEA (2018) https://www.eea.europa.eu/publications/COR0-landcover
[11] Ingalls., M. M., 1981. Estimating mobile source pollutants in microscale exposure situations. US Environmental Protection Agency. EPA-460/3-81-021
[12] 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

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[13].

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[14]. The scientific basis for the model is presented in a series of papers by the Met Office[15,16,17,18,19]. The model formulation shares a high level of commonality with the Operational Street Pollution Model[20][21] (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.

Using available information on building heights and road widths, candidate locations for street canyons were identified. These locations were then checked using Google Street View to confirm the presence of a street canyon. For roads assigned as street canyons, the required information for the AEOLIUS street canyon model was populated – this includes building height, emissions and number of vehicles per hour. The canyon model is only turned on if the wind is blowing parallel across the canyon (± 5 degrees) i.e. the wind must be between 40 and 50 degrees from the orientation of the canyon. For each hour in the meteorological data (same as that described in 3.2.2) with wind direction matching the criteria to turn the street canyon on, the leeward, windward and parallel street canyon concentrations were calculated. To provide annual street canyon concentrations, the sum of the data contained within each of leeward, windward and parallel was calculated.

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

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[22]. 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. Defra's Joint Air Quality Unit (JAQU) have instructed dispersion modelling of English CAZs to gradient adjust all pre-Euro VI HDVs, this has been undertaken for Cardiff. Figure 7 shows the roads where gradient effects were included during emissions calculations.

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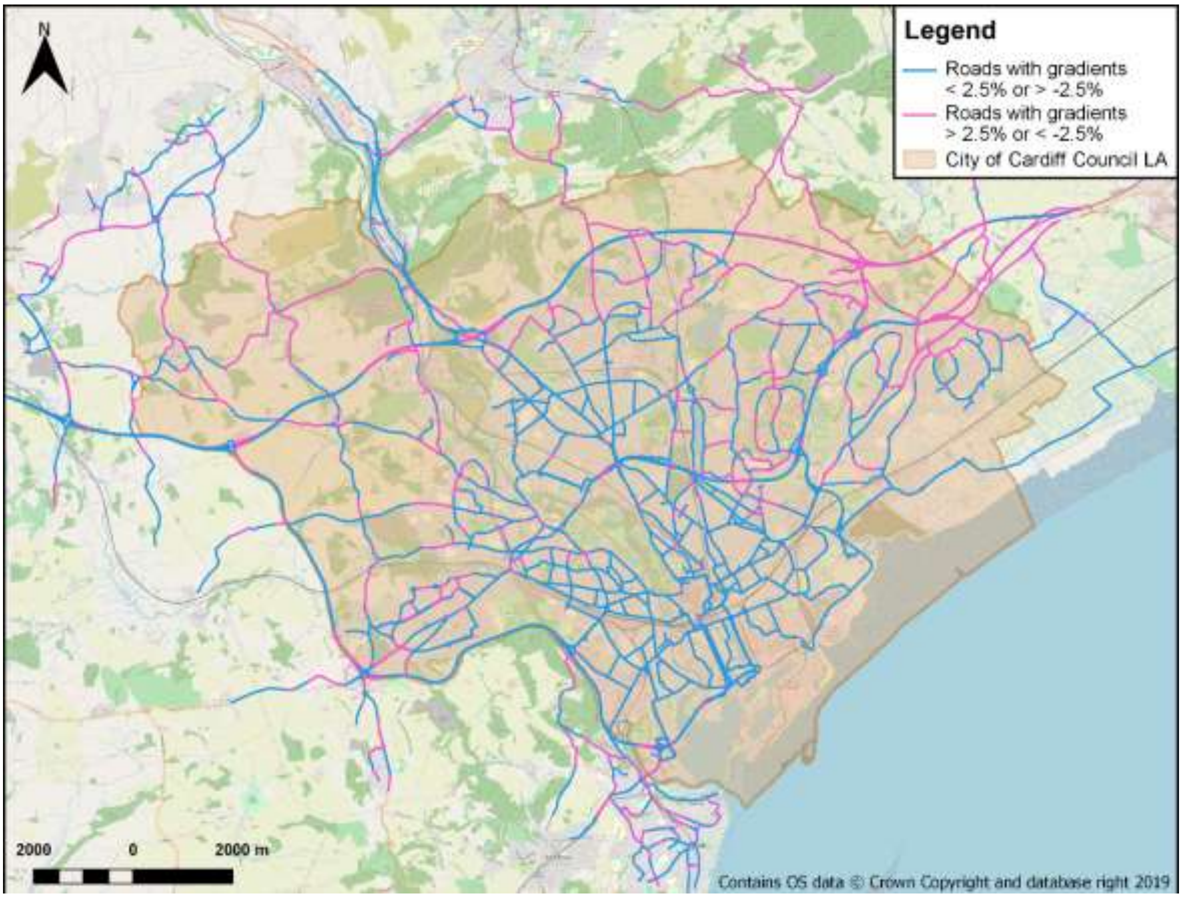
[13] http://www.eea.europa.eu/publications/TEC11a/page014.html
[14] Buckland AT and Middleton DR, 1999, Nomograms for calculating pollution within street canyons, Atmospheric Environment, 33, 1017-1036.
[15] Middleton DR, 1998, Dispersion Modelling: A Guide for Local Authorities (Met Office Turbulence and Diffusion Note no 241: ISBN 0 86180 348 5), (The Meteorological Office, Bracknell, Berks).
[16] Buckland AT, 1998, Validation of a street canyon model in two cities, Environmental Monitoring and Assessment, 52, 255-267.
[17] Middleton DR, 1998, A new box model to forecast urban air quality, Environmental Monitoring and Assessment, 52, 315-335.
[18] 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.
[19] Middleton DR, 1999, Development of AEOLIUS for street canyon screening, Clean Air, 29(6), 155-161, (Nat. Soc for Clean Air, Brighton, UK).
[20] 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).
[21] 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).
[22] http://environment.data.gov.uk/ds/survey/#/survey

Figure 7: Locations where gradient effects have been included during emission calculations



No modelling of tunnels or flyovers was included as the RapidAir kernel approach applies the same source height across the model domain. All roads provided by the traffic modellers within CCC boundary were modelled at ground level, this includes both flyovers and tunnels. For example, in Figure 7 it can seen that the A4232, Cardiff Bay Link Road, flyover and tunnel have been included. 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.

3.3 Receptor locations

Cardiff 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 6 in relation to the modelling domain.

The RapidAir model can deal with about 1.2 billion gridded locations which provides for over 30,000 cells in the 'x' and 'y' axes. We can therefore model 40km x 30km, which is roughly the size of the Cardiff modelling domain, down to a 1m resolution. Therefore, we have used this 1m resolution for our work in Cardiff. 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.

Cardiff has four AQMAs all of which contain numerous sensitive receptors. RapidAir, by virtue of its very high-resolution outputs, can produce discrete estimates at every single residential property in Cardiff (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.

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 10m intervals along relevant road links using a 4m buffer around the carriageway polygons. For Cardiff's modelling exercise concentrations were sampled at 4m from the kerbside and at a height of 1.5 metres.

This resulted in a total of 20,142 discrete sampling points. Geospatial analysis permitted point allocation to the closest Census IDs used within the PCM model. The maximum estimated concentration at discrete receptors representative of Census IDs were used for this localised dispersion modelling study. Consequently, the worst-case modelled concentrations are being used in comparison with those from the PCM model.

It should be noted that relevant exposure to the annual mean NO_2 EU limit value could be within less than 4 metres from the kerb. The highest concentrations in the whole model domain are predicted along census link 30665. According to the definitions of relevant exposure within LAQM.TG(16) there are no areas with relevant exposure at 4 metres or less at a height of 1.5 metres. Modelling receptors at a distance of 4m has not resulted in any potential areas of exceedance from being excluded from this modelling exercise.

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.

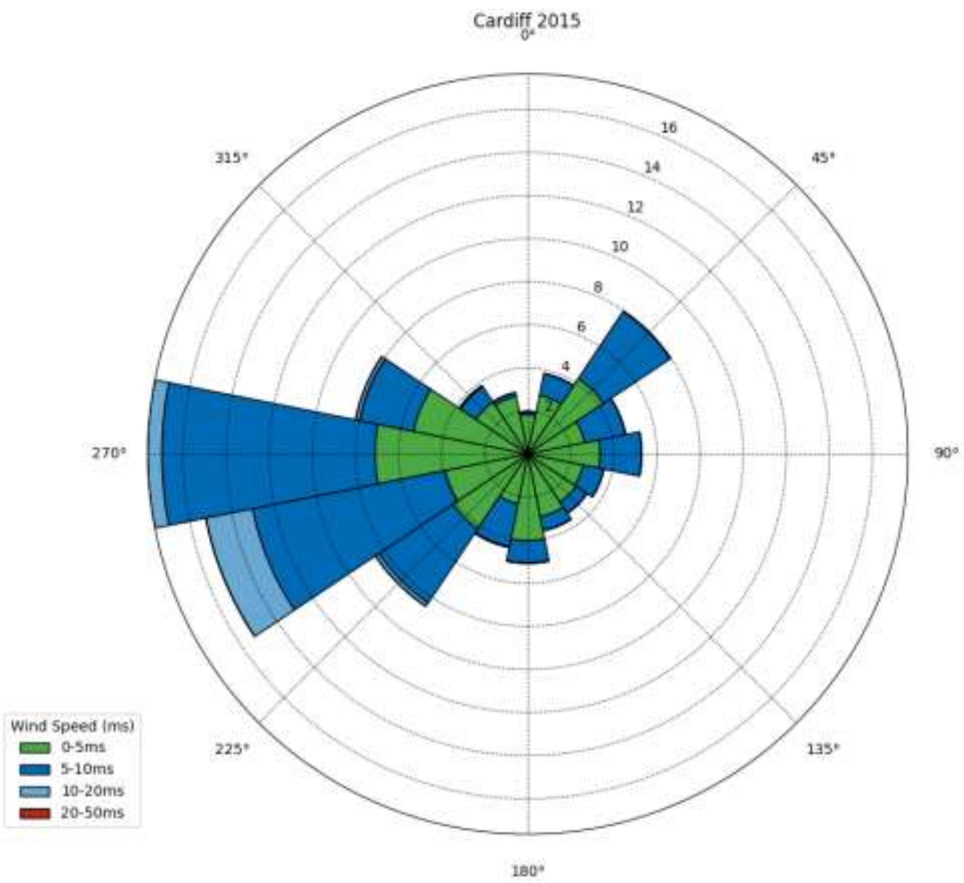
Annex III of the AQD also specifies that microscale sampling should be at least 25 m from the edge of major junctions. When reporting model results relevant to compliance with the AQD, locations up to 25m from the edge of major junctions in the model domain have also been excluded.

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 Cardiff City Centre 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 Cardiff City Centre met dataset is presented in Figure 8.

Figure 8: Windrose

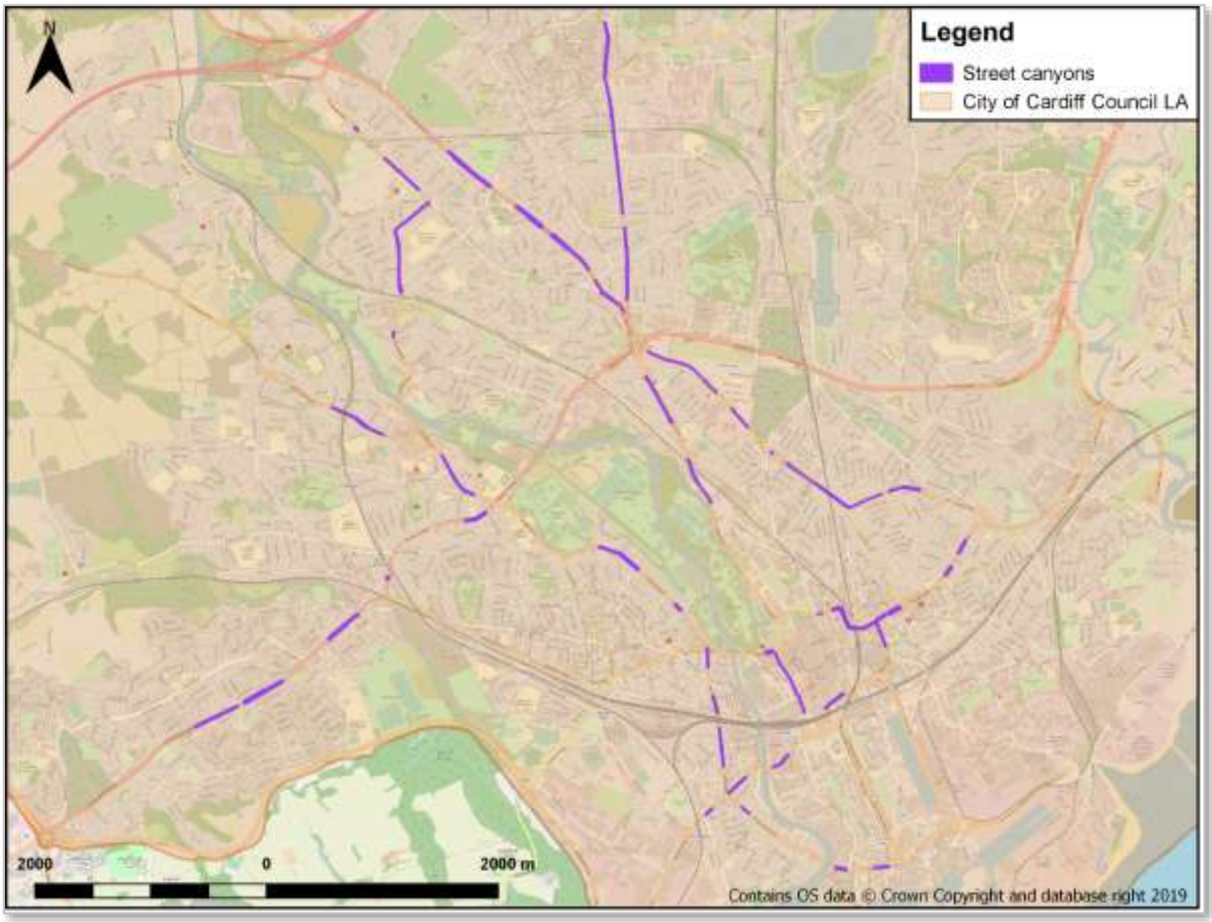


4.2 Representation of road locations and canyons

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 were provided by Mott Macdonald using outputs from the South East Wales Transport Model (SEWTM) that covers the areas of Cardiff, Newport, Caerphilly and east of Swansea. Traffic flows were provided for the following vehicles types; Cars, light goods vehicles (LGV), heavy goods vehicles (HGV) and buses. It should be noted that the bus traffic flows only include service operators. This means that modelled buses do not include coaches or mini-buses and will be under-estimation of bus movements.

Speeds were provided for four modelled period: AM (peak hour 07:45-08:45), Inter-Peak (average of period 09:30-15:30), PM (peak hour 16:30-17:30) and Off-peak (average between 18:00-07:00). Ricardo calculated the AADT equivalent speeds with a weighted average. This involves summing the multiplication of each peak hour speed by the corresponding period traffic flow and dividing by AADT, see equation below.

$$AADT\ speed = \frac{(AM\ phs \times AM\ ptf) + (IP\ aps \times IP\ ptf) + (PM\ phs \times PM\ ptf) + (OP\ aps \times OP\ ptf)}{AADT}$$

Where: *phs = peak hour speed*
ptf = period traffic flow
aps = average period speed

In traffic modelling there is an area of detailed modelling (AODM) and rest of area (ROF), the former denotes areas where the traffic modellers have greater accuracy in traffic forecasts and the latter less accuracy. It has been confirmed all roads links included in the dispersion modelling exercise are within the AODM. Further information on how the baseline 2015, 2021 and other scenarios have been represented within the SEWTM model can be found within the traffic modelling chapter[23].

An extensive 2015 Automatic Traffic Count (ATC) survey was undertaken in support of the SEWTM model. An ATC survey provides total number of vehicles across a number of vehicle categories for a 15 minute period over the duration of the survey. This survey provides data required to establish the proportion of traffic that is contributed to a daily total from up to a resolution of 15 minutes. Thereby enabling the development of a diurnal profile which establishes the proportion each hour contributes to a 24-hour period total. Only ATC locations across Cardiff, which were considered representative of the model domain were used in the development of this diurnal profile. One diurnal profile was developed for all vehicle types and applied as time varying emissions in AERMOD when creating the RapidAir dispersion kernel.

4.3.2 Vehicle fleet composition

The 4 core vehicle fleet types are; cars, LGVs, HGVs and buses. The subcategories of these vehicles types with emission rates are;

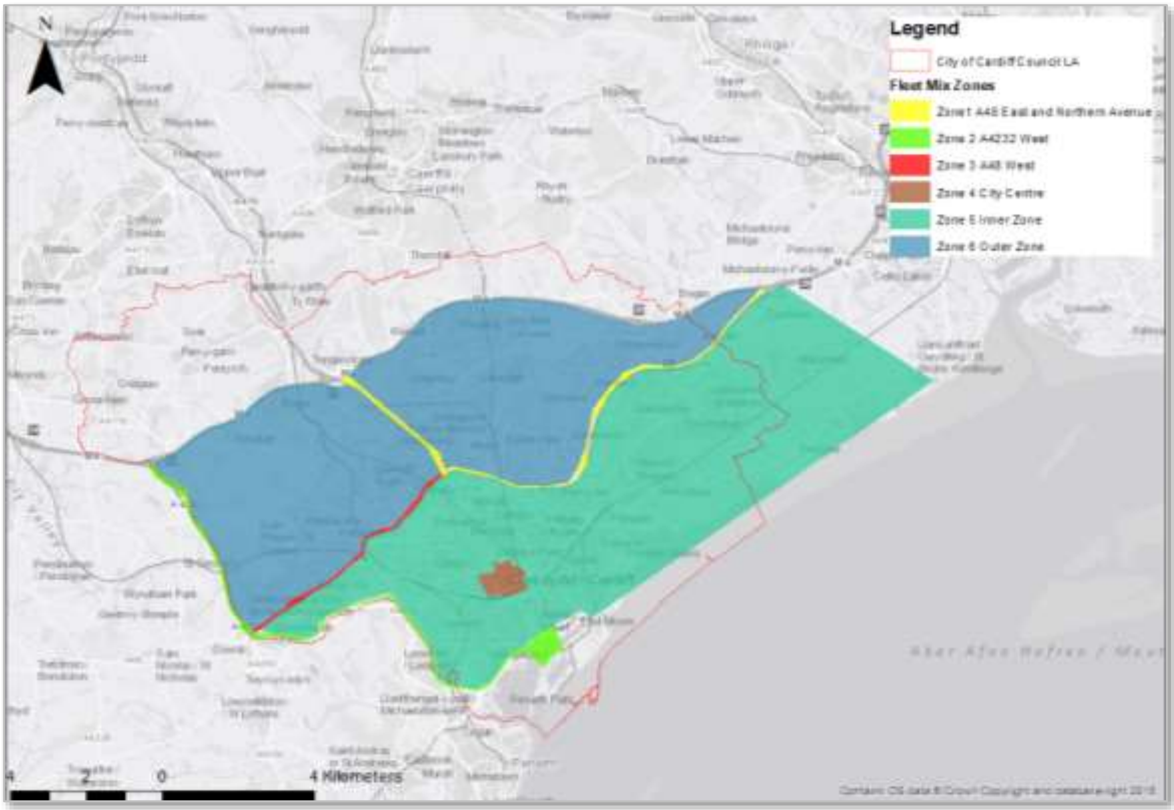
- **Cars:** are split into passenger/private, private hire taxis and hackney taxis;
- **LGVs**: there is no split for LGVs;
- **HGVs**: are split into articulated HGVs and rigid HGVs; and
- **Buses:** there is no split for buses.

These can be calculated using the latest COPERT v5 NOx emission functions.

The traffic model provided vehicle flows for four highway user classes which are: Car, HGV, LGV and Buses. HGVs were further broken down into rigid and articulated and cars were divided into private hire and Hackney taxis subcategories, this was undertaken using Automatic Number Plate Recognition (ANPR) data. ANPR locations were selected if they were in an area of key concern for air quality. This includes AQMAs and non-compliance links in the PCM model. ANPR cameras were setup at 12 locations, recording various directions of traffic resulting in 21 unique records. To ensure that fleet mixes most accurately represented these key air quality areas 7 unique zones were created, as per Figure 10. Zone 7 is an average fleet mix derived from all the ANPR cameras across Cardiff. This has been applied to roads which are outside zones 1-6.

[23] 367590 Air Quality Transport Modelling Technical Note CASAP CAZ.pdf

Figure 10 Cardiff Fleet Mix Zones



The ANPR survey lasted for a week over a traffic neutral period i.e. during term time and is representative of a years' typical weekly traffic. The ANPR survey enables emission rates from road traffic to be represented in the greatest detail possible within COPERT V, which includes:

1. Cars, split between Petrol and Diesel from pre-euro standards up to Euro 6 and alternative technologies such as electric and plug in hybrids;
2. Light Goods Vehicles (LGV) (<3.5 tonnes), split between Petrol and Diesel from pre-euro standards through to Euro 6; LGVs consist of Vans and People Carriers e.g. large passenger cars and mini-buses.
3. Rigid and Artic Heavy-Goods Vehicles (HGV), from pre-euro standards through to Euro 6.
4. Bus and Coach, from pre-euro standards through to EURO VI.
5. Motorcycles are an option within COPERT, however, the NAEI defaults for 2015 and 2021 have been used.

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 12th to 19th May 2018. The scenarios included in dispersion modelling are baseline 2015, baseline 2021, CASAP1, CASAP2, CASAP 3 and the City Centre Clean Air Zone 1 and 2. From this, there are 2 unique years which should be considered in the calculation of the fleet mix, 2015 and 2021. As the ANPR survey was undertaken in 2018, National Atmospheric Emission Inventory's (NAEI) fleet mix projections were used to back-cast to 2015 and forecast to 2021. The distribution of fuel type and Euro classification from the 2018 local data average across all the ANPR locations is shown in Figure 11 to Figure 16 below compared to the 2018 national average data taken from the (NAEI).

Representing Fleet Mixes with ANPR data

There were approximately 2.6 million ANPR records, which have been matched to the DVLA database. Each individual vehicle which has been captured and matched to the DVLA database has had a vehicle type assigned by TRACSIS. TRACSIS are the traffic survey specialist which provided the ANPR data. Further detail provided includes the vehicle type associated with each vehicle captured e.g. Car, Private Hire Vehicle (PHV), Hackney, PSV (buses and coaches), OGV1 (Rigid HGV) and OGV2 (Artic HGV). As mentioned above, there are euro standards for each of the vehicle types, as such these have been associated and used within the COPERT V emission calculations. This assumes that TRACSIS have correctly linked each vehicle type to each category.

Using Euro standards for PSVs, as defined by ANPR data, for exclusively buses will mean that coaches will result in a slight misrepresentation of Euro standards. This is the case for buses in emission calculations, as only buses from service operators within Cardiff have been included in the bus traffic flows from the traffic model. When comparing bus Euro standards from only Cardiff Bus's fleet to those within the ANPR data, Cardiff bus have a much more polluting fleet with 82.5% being pre-Euro VI. Whereas the % of pre-Euro VI standard PSVs within the ANPR data is only 61.7%. Which will mean that emission contribution from buses are being under-represented, however these discrepancies have been offset during the model validation process. This compares modelled NO_x against measured NO_x taking a regression result across all validation locations to adjust modelled results.

Figure 11 Car fuel type split

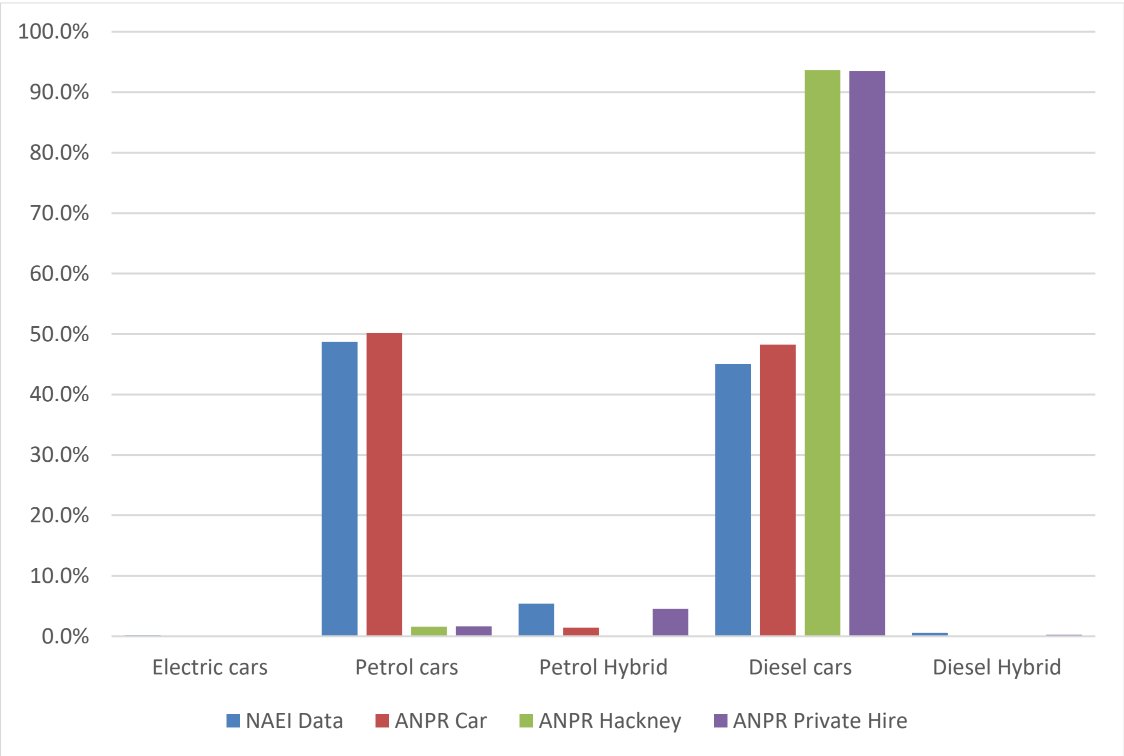


Figure 12 Diesel car Euro classification distribution

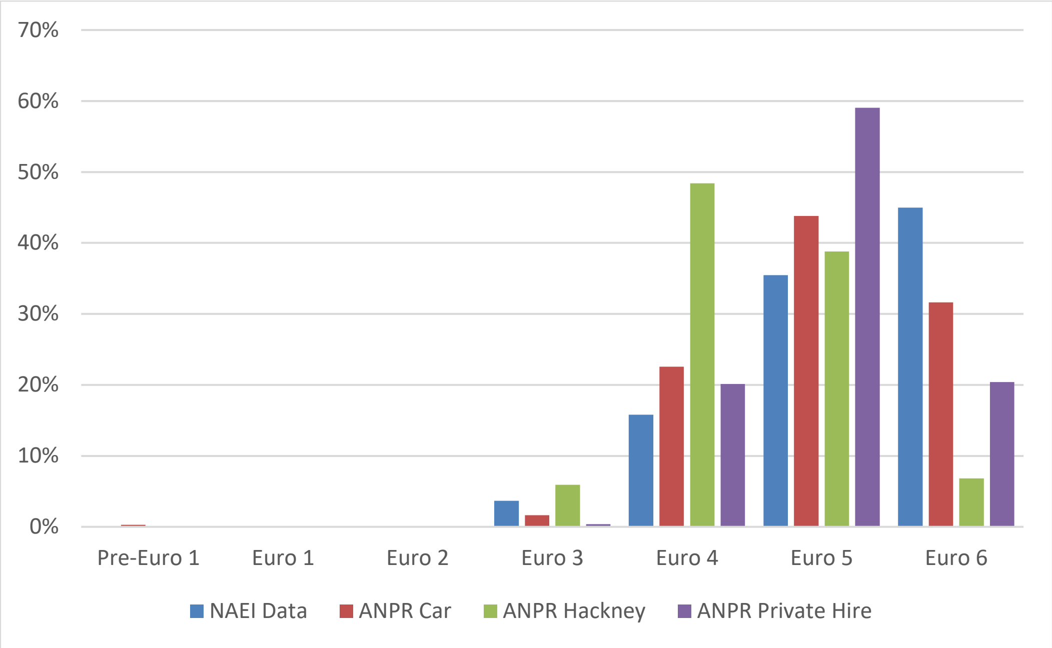


Figure 13 Petrol car Euro classification distribution

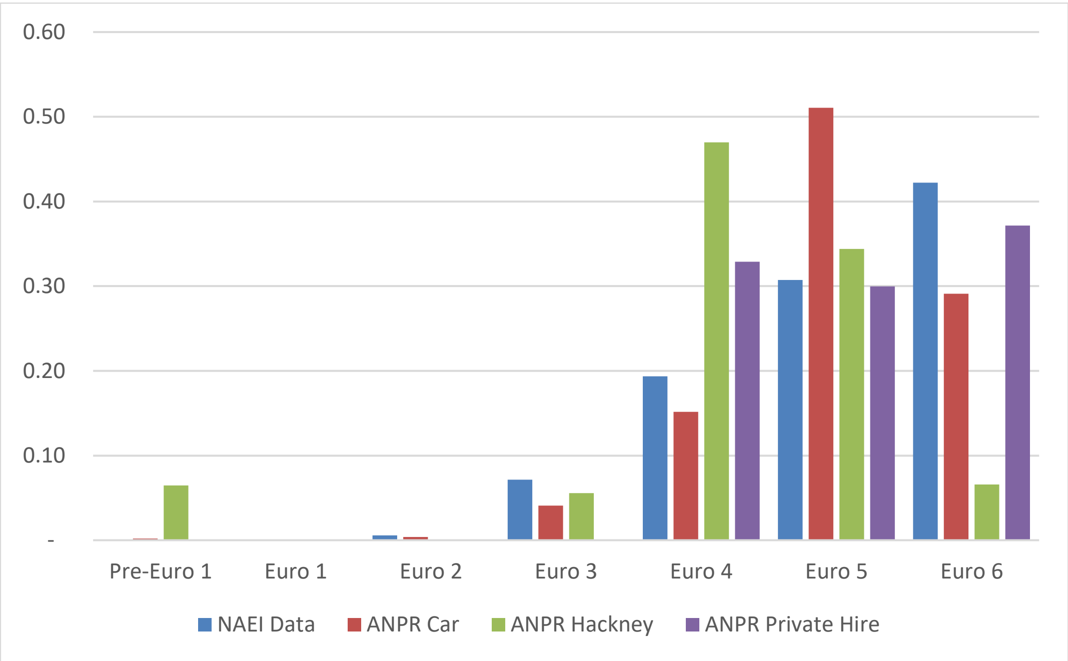


Figure 14 Diesel van Euro classification distribution

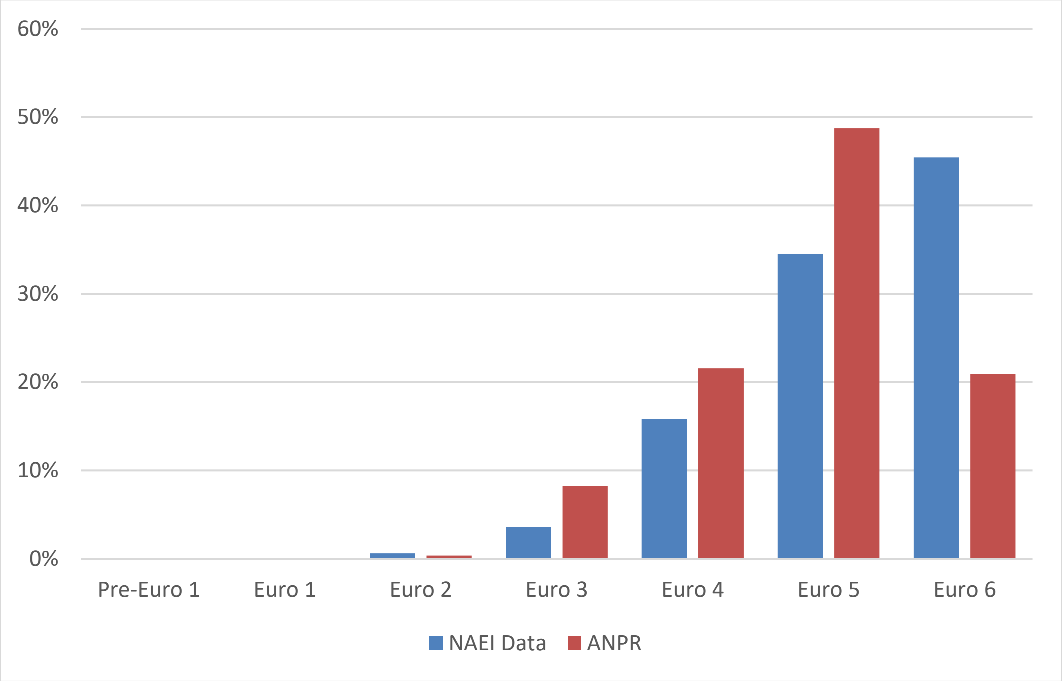


Figure 15 Rigid HGV Euro Classification distribution

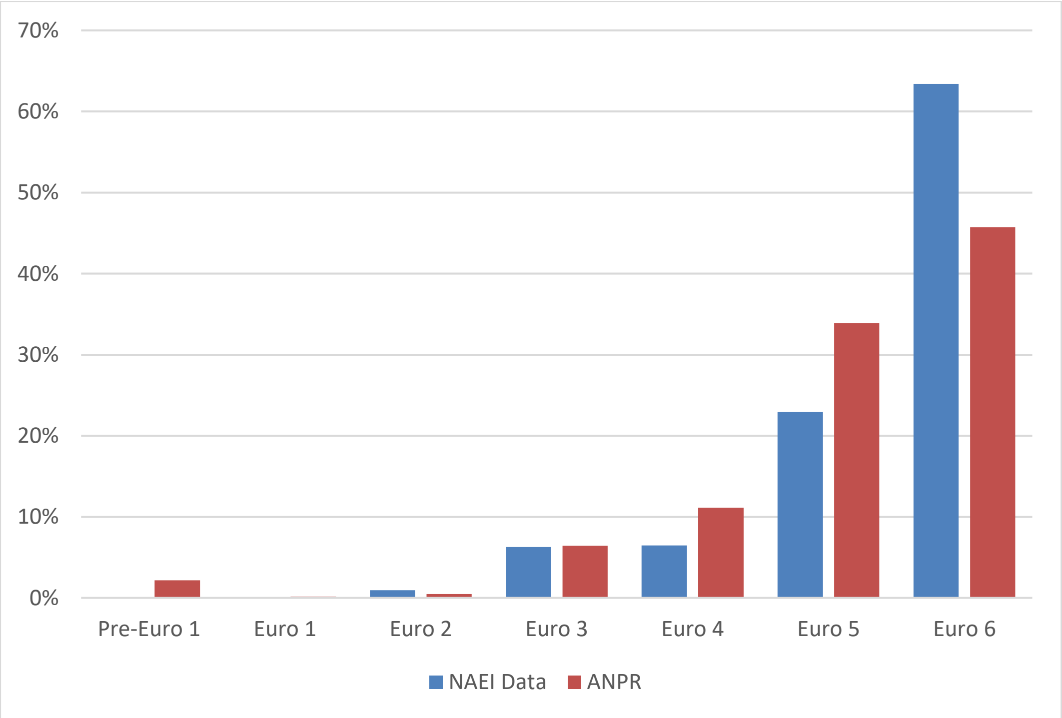
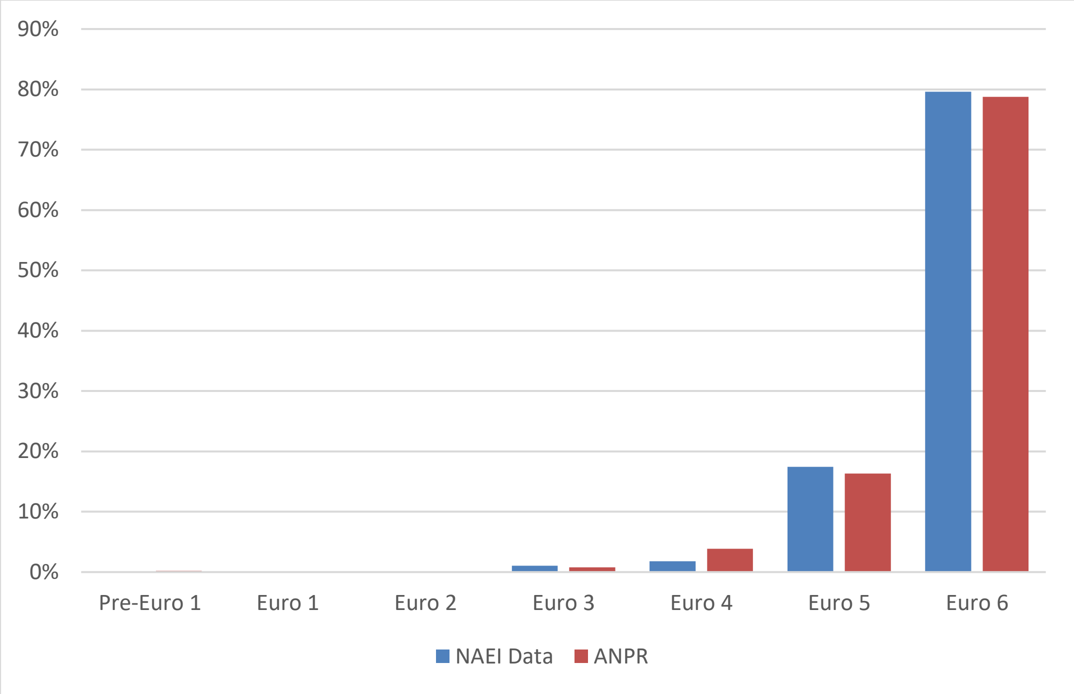


Figure 16 Artic HGV Euro Classification



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 RapidEms, 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 RapidEms road emissions calculation tool now includes additional functionality to calculate NO_2 emission rates for each road link. Link specific fNO_2 fractions can then be calculated for each link by dividing NO_2 by total road NOx emission rate. Calculating link specific NO_2 emission rates also facilitates dispersion modelling of both road NOx and NO_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 (v6.1) 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.

4.4 Non-road transport modelling and background concentrations

We have considered two types of non-road transport sources of NO_x emissions (or background concentration) data.

1. **Large local point sources**: A review of large point sources such as Part A processes regulated by the Environment agency included in NAEI was undertaken. No locations were considered close enough to Cardiff's modelling domain for to carry out separate dispersion modelling. For example, the majority of point sources do not contribute a substantial tonnage of NOx, with the exception of a steel manufacturing plant and an energy from waste installation. However, as this assessment estimates NO_2 annual mean in the same areas of the PCM model, it is only when PCM links are within close proximity that further consideration is required. The closest source is 770m upwind from PCM roads and it is considered that representation of these sources in Defra's background concentrations sufficiently represents background contributions.

2. **Sm**all **local point sources:** The European Pollutant Transfer Register (PRTR) has been reviewed and the majority of registered A2 and B permitted processes were screened out for insignificant contributions to NOx for example cement batching and mineral processing. However, there are a few additional sources which were considered further. A galvanising factory near the Bute East Dock was screened out due to a distance of >600 metres to roads included in the PCM model. Background contributions from a crematorium 200 metres downwind of census ID 99671 were not included in dispersion modelling. It was considered that NOx contributions through dispersion modelling will not be significantly different to Defra's background industrial contributions. As such process contributions represented within the Defra's background maps were considered satisfactory.

3. **Rail emissions:** Cardiff concluded in their 2009 updated and screening assessment that emissions from rail did not need to be considered further. Consequently, emissions from rail were considered to be satisfactorily represented by Defra's background concentrations.

4. **General background sources:** The 1km resolution LAQM background maps were used to provide estimates for all sources with the exception of motorway, primary and trunk roads contribution.

To avoid double counting of modelled road transport sources motorway, primary and trunk roads contributions were discounted from Defra's background maps.

4.5 Measurement data for model calibration

CCC's 2015 automatic and diffusion tube annual mean NO_2 measurements from roadside sites were considered for model verification. Further information on model verification has been presented within Appendix 1. Information on monitoring data QA/QC, diffusion tube bias adjustment factors etc. will be as presented in the CCC's 2016 LAQM Annual Progress Report.

5 Projected future year scenario modelling

5.1 Road transport future year baseline

The assessment year for all future scenarios is 2021. The basic projections used for the future year baseline scenario are:

- **AADT flows for future baseline year** were provided from the SEWTM. Further information on how these traffic flows were derived and how local growth in traffic is calculated is presented in 'Transport Modelling Methodology Report'[24].
- **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 HGVs into artic and rigid, and cars into private hire and hackneys 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 projection 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. This can be seen in Figure 12 through to Figure 16, which shows that the average Euro classes across all ANPR sites have a slower uptake of Euro VI than NAEI.
- **Compliance split for future fleet** All future scenarios, including the baseline 2021 scenario, have a separate fleet mix for compliant and non-compliant vehicles. The projected 2021 Euro standards for different vehicle types were split into categories of compliant and non-compliant. The Euro standards which fit into these two categories are listed within Table 4.

Table 4 vehicle type Euro standards categorised as compliant/non-compliant

Compliant				Non-Compliant			
Car	Vans	HGV – Rigid/Artic	Bus	Car	Vans	HGV – Rigid/Artic	Bus
Euro 4-6	Euro 4-6	Euro VI	Euro VI	Euro-3 and older	Euro-3 and older	Euro-V and older	Euro-V and older

Ricardo provided the 2015 and 2021 compliance split at each ANPR location to enable the traffic modellers to split their highway matrices (vehicle categories) into compliant/non-compliant vehicle types. As a result, traffic model outputs provided contained traffic flow (AADT) accompanied with a compliant/non-compliant factor for all modelled vehicles. This was used to apportion traffic flows to the compliant/non-compliant fleet mixes.

- **Future year scenarios average vehicle speed data:** The same volume-weighted average speed approach mentioned in section 4.3.1 was adopted for the future baseline scenarios. The same speeds were applied to both compliant and non-compliant vehicles.
- **Projected vehicle NOx emission rates** will be calculated using the latest COPERT v5 NOx emission functions applied to AADT, speed, fleet and vehicle age composition for each future baseline year being modelled.

5.2 Scheme option modelling projections

This section provides the modelling methodology for the CASAP and CAZ scenarios as reflected in air quality modelling, see Table 1 for information on measures included in traffic modelling.

[24] 367590 Air Quality Transport Modelling Technical Note CASAP CAZ

5.3 CASAP 1 and 2

Measures accounted for in the emissions modelling: Taxi Licensing (Euro 6 for new licensees) and electric buses on service routes 27, 49/50 and 44/45. As noted within Table 1 the transport modelling methodology incorporates the remainder of the CASAP 1 and CASAP 2 measures. The effects of these changes are reflected within the traffic flows and compliance split provided by the traffic modelling and therefore emission calculations undertaken as part of the dispersion modelling. Consequently, it is only the taxi and electric buses measures that have specific assumptions within the air quality methodology to reflect changes upon the fleet and subsequent emission calculations for CASAP 1 and 2.

- **Taxi licensing:** information on private hire vehicles and hackneys registered with CCC was provided by the Council's licensing department. In addition, the ANPR data to produce Euro standards for the taxi fleet mix. Since the Euro standards defined by the ANPR dataset and from CCC's taxi licensing result in a different Euro standard composition (one is based on trips and the other vehicle numbers) a % shift approach was used to assess the impact of the licencing change. The taxi information included the number of taxis which fall into 3 age categories; 10 years or older, between 10 and 4 years old and under 4 years old of registered taxis. This was used to determine the current % of the taxi fleet naturally compliant. It has been assumed that all vehicles which are older than 10 years will register a new taxi under 5 years. This results in an 18% increase in the number of compliant taxis. This was used as an adjustment factor to shift 18% of the non-compliant (i.e. non Euro 6) taxi traffic flows (AADT) to compliant taxi traffic flows (AADT) for all roads in the study area.
- **Zero Emission Buses (ZEB):** The ambition of ZEB is to implement 36 electric buses on Cardiff City Buses' service routes. These would replace the oldest vehicles in the fleet and so the remaining fleet would consequently have a newer profile. There are 3 service routes which are being targeted with ZEB buses; 27, 49/50 and 44/45. This has been reflected in emission calculations of buses in the following way:
    - **Electric buses:** This modelling exercise only focuses upon dispersion modelling of NO_2. As such an electric bus produce zero NO_2 emission and so a fleet penetration % has been calculated to reduce bus traffic flows emissions are calculated with.
    - **Electric buses:** The % ZEB reductions were applied to the routes on which the buses operated. It is assumed that every service contributes an equal number of bus traffic flows along the route and so the ZEB reduction are only applied in proportion to the ZEB services along that route. This generates the % reduction in bus traffic flows assumed for roads used by ZEB targeted services is as follows:
        - **27:** a 20% reduction in bus traffic flows;
        - **44/45:** a 14% reduction in bus traffic flows; and
        - **49/50:** a 14% reduction in bus traffic flows.
    - **Bus fleet turnover:** The introduction of ZEBs will allow the older buses to be phased out. CCC provided Ricardo with the Euro standard details of Cardiff City Bus's fleet. This enabled the % of compliant buses to be calculated for Cardiff City Bus before the introduction of ZEB. CCC intend to replace 36 Euro 3 buses with ZEBs. Consequently, the effects of fleet turnover upon the % of compliant buses was calculated and resulted in a 3.26% shift from compliant to non-compliant buses. The actual Euro standards used for emission calculations was derived from an ANPR survey projected to 2021. Using the Cardiff City Bus's Euro standard mix with ZEB directly would be a change in methodology. As such, the 3.26% shift to compliant buses with ZEB was used as an an adjustment factor to transfer bus traffic flows (AADT) from non-compliant to compliant bus emission calculations.

5.4 CASAP 3

The measures reflected in air quality modelling is the retrofitting of all buses to Euro VI. In this case all remaining non-electric buses were assumed to be Euro VI in the emissions calculations.

5.5 CAZ 1

This is a charging clean air zone which encompasses the inner-city centre, and is bordered by the following roads A4119, A4160 and A4161 as shown Figure 3. The charge of £10 associated with CAZ 1 applies to cars only and the behavioural response in relation to this charge has been based upon a JAQU default response data (taken from modelled responses to the London ULEZ). The majority of the upgrade assumption recommended by JAQU have been outlined within the transport modelling report. These are based on a £12.50 charge and have been scaled down to reflect the £10 charge. The traffic model outputs generated, and used in the air quality modelling, then take account of re-distribution of traffic and the affect upon proportions of compliant/non-compliant vehicles. The emissions model then takes this new split of compliant vehicles and associate it with the mix of euro standards outlined in Table 4 when calculating emissions.

The one JAQU upgrade assumption which has not been reflected in traffic modelling and therefore reflected in directly in the emission calculations is the change to petrol and diesel proportions. As would be expected the number of naturally compliant petrol vehicles is much higher as older petrol vehicles (2006) are classed as compliant. The JAQU upgrade assumptions account for this with a shift from non-compliant diesel to older compliant petrol vehicles.

It is assumed that the mix of compliant and non-compliant petrol/diesel euro standards are the same before and after the CAZ. To elaborate on this, there is no upgrade assumption to a specific euro standard only that the vehicle is compliant.

5.6 CAZ 2

The CAZ 2 charging clean air zone covers the exact same area as CAZ 1. However, only goods vehicles are targeted, with a planned charge for LGVs at £10 and HGVs £50. As with CAZ 1, these charges are less than the generic JAQU charges (based on the London ULEZ) and subsequently upgrade assumptions have been scaled down by the traffic modellers.

The JAQU upgrade assumptions also have a shift from petrol to diesel, like that assumed for cars, for the LGVs and this is handled directly in the emissions model.

5.7 Preferred CASAP

Measures accounted for in the emissions modelling: Taxi Licensing (Euro 6 for new licensees) and electric buses on service routes 27, 49/50 and 44/45. As noted within Table 1 the transport modelling methodology incorporates the remainder of the preferred CASAP measures. The effects of these changes are reflected within the traffic flows and compliance split provided by the traffic modelling and therefore emission calculations undertaken as part of the dispersion modelling. Consequently, it is only the taxi, electric buses and bus retrofit measures that have specific assumptions within the air quality methodology to reflect changes upon the fleet and subsequent emission calculations for this scenario:

Taxi licensing: several changes have been made from the taxis measure in the outline case and comprises:

- Updated taxi licencing numbers against the age criteria were provided, with a greater number needing to renew and upgrade. Consequently, it has been assumed that all PHVs and Hackneys which are older than 10 years will register a new taxi under 5 years, this results in a 16.59% and 45.35% increase in the number of compliant vehicles, respectively. This was used as an adjustment factor for specific taxi types to shift the non-compliant (i.e. non Euro 6) taxi traffic flows (AADT) to compliant taxi traffic flows (AADT) for all roads in the study area.

  - A ULEV incentive uptake assumption for those renewing of 5% for hackney cabs and 20% for private hire. All ULEV upgrades were assumed to be zero emission. This provided a proportion of renewals that would upgrade to zero emission rather than Euro 6 diesel. This resulted in 4% of compliant hackneys and 7% of compliant PHVs being zero emission. These were then removed from the compliant taxi AADT in the emission calculations.

- **Zero Emission Buses (ZEB):** this remains unchanged from the assumptions set out above for CASAP 1 and 2.
- **Bus Fleet Retrofit Programme:** this is a scaled back version of bus upgrades within CASAP 3, with the ambition of upgrading only 80% of non-compliant buses. This reduces the number of non-compliant bus flows remaining after zero emission bus fleet turnover by shifting 80% of remaining bus traffic flows into compliant bus emission calculations.

5.8 Sensitivity Analyses

This section outlines assumptions behind sensitivity analyses carried out in the air quality modelling. Three key sets of tests were carried out:

- *Low performance of Euro 6 vehicles* – This test was carried out to assess the impact of Euro 6 light duty vehicles not performing as well as expected in terms of emissions performance. For this test all light duty Euro 6 vehicles were set to the base Euro 6a standard in the model. This test was carried out for the 2021 baseline scenario and preferred CASAP option.
- *Lower fNO_2 by 40%* - this test was carried out to consider the impact of lower fNO_2 as part of the NOx to NO_2 conversion process. This was done as new evidence is suggesting the fNO_2 may be lower than previously considered for newer vehicles. The test was to reduce fNO_2 by 40% for the NOx to NO_2 conversion process. This test has been carried out for the 2021 baseline and preferred CASAP option.
- *CASAP low test* – this test was used to assess the impact of more pessimistic assumptions in relation to the performance of the CASAP measures. The key assumptions where uncertainly was greatest and where a lower assumption was used were:
  - Uptake of the bus retrofit programme – this was reduced from 80% to 50%;
  - Zero uptake of the ULEV taxi grant;
  - A reduction in the mode shift impact of the active travel measures from 3% to 1%.

Appendix 1: Model Verification

Verification of the model involves comparison of the modelled results with any local monitoring data at relevant locations; this helps to identify how the model is performing and if any adjustments should be applied. The verification process involves checking and refining the model input data to try and reduce uncertainties and produce model outputs that are in better agreement with the monitoring results. This can be followed by adjustment of the modelled results if required. The LAQM.TG(16) guidance recommends making the adjustment to the road contribution of the pollutant only and not the background concentration these are combined with.

The approach outlined in LAQM.TG(16) section 7.508 – 7.534 has been used in this case. All roadside diffusion tube NO_2 measurement sites in Cardiff have been used for model verification. A single road NOx adjustment factor was derived and used to calculate:

- Citywide modelling results at receptor points adjacent to relevant PCM road links.
- Citywide 1m resolution NO_2 annual mean concentration rasters providing a continuous representation of the spatial variation in modelled concentrations.

It is appropriate to verify the performance of the RapidAir model in terms of primary pollutant emissions of nitrogen oxides (NOx = NO + NO_2). To verify the model, the predicted annual mean Road NOx concentrations were compared with concentrations measured at the various monitoring sites during 2015. The model output of Road NOx (the total NOx originating from road traffic) was compared with measured Road NOx, where the measured Road NOx contribution is calculated as the difference between the total NOx and the background NOx value. Total measured NOx for each diffusion tube was calculated from the measured NO_2 concentration using the latest version of the Defra NOx/NO_2 calculator (v6.1).

The initial comparison of the modelled vs measured Road NOx identified that the model was under-predicting the Road NOx contribution at most locations. Refinements were subsequently made to the model inputs to improve model performance where possible.

The gradient of the best fit line for the modelled Road NOx contribution vs. measured Road NOx contribution was then determined using linear regression and used as a domain wide Road NOx adjustment factor. This factor was then applied to the modelled Road NOx concentration at each discretely modelled receptor point to provide adjusted modelled Road NOx concentrations. A linear regression plot comparing modelled and monitored Road NOx concentrations before and after adjustment is presented in Figure 17.

The total annual mean NO_2 concentrations were then determined using the NOx/NO_2 calculator to combine background and adjusted road contribution concentrations.

Some clear outliers (n = 7) were apparent during the model verification process, whereby we were unable to refine the model inputs sufficiently to achieve acceptable model performance at these locations. These sites were excluded from the model verification. The reasons why acceptable model performance could not be achieved at these sites include:

- Sites located next to a large car park, bus stop, petrol station, or taxi rank that has not been explicitly modelled due to unknown activity data.
- No traffic model road link included where the NO_2 sampler is located, or not all road links included e.g. at a junction.

The RapidAir canyon allocator identified Westgate Street as a canyon, however including a canyon in this location leads to very scattered data in the model verification and the sites located in this canyon do not follow the general trends shown by the remainder of the monitoring locations. Consequently, the canyon in Westgate was manually removed which resulted in the relationship between measured and modelled concentrations at sites in this street following similar trends to the other verification sites, and reduced the error in the model predictions.

To present a conservative approach to adjusting future year predictions of road NOx concentrations, a primary NOx adjustment factor (PAdj) of 1.807 based on model verification using all of the 2015 NO_2 measurements was applied to all modelled Road NOx data prior to calculating an NO_2 annual mean.

A plot comparing modelled and monitored NO_2 concentrations before and after adjustment during 2015 is presented in Figure 18.

Figure 17: Comparison of modelled Road NO_x Vs Measured Road NO_x before and after adjustment

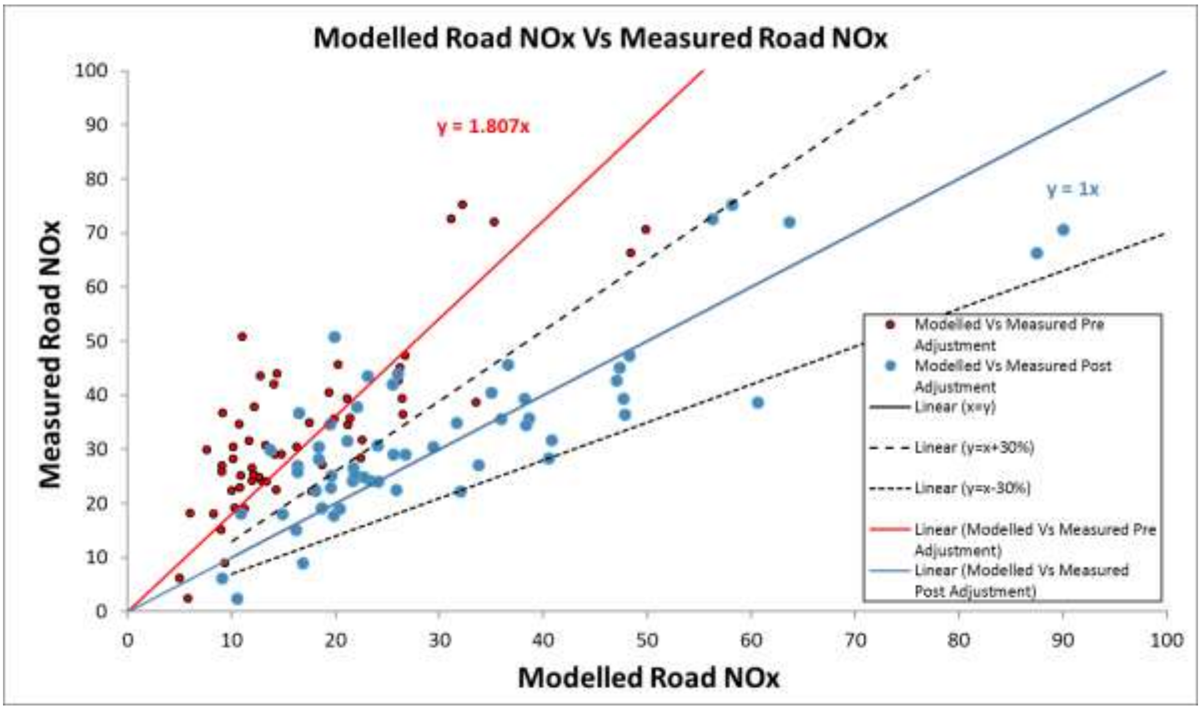
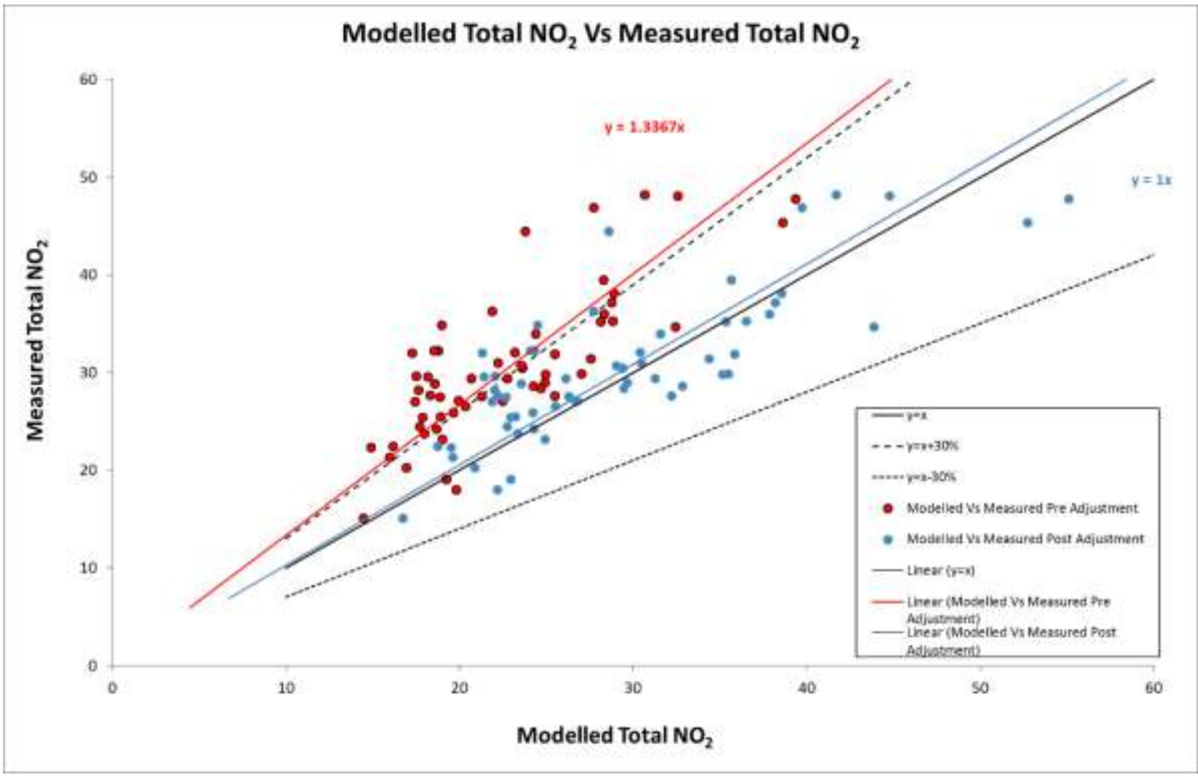


Figure 18 Modelled vs. measured NO_2 annual mean 2015 before and after adjustment



Model performance

To evaluate the model performance and uncertainty, the Root Mean Square Error (RMSE) for the observed vs predicted NO_2 annual mean concentrations was calculated, as detailed in Technical Guidance LAQM.TG(16). This guidance indicates that an RMSE of up to 4 µg/m^3 is ideal, and an RMSE of up to 10 µg/m^3 is acceptable. The calculated RMSE is presented in Table 5. In this case the RMSE was calculated at 5.1 µg.m^{-3}which is close to the ideal range suggested by the guidance.

Table 5 Comparison of measured and modelled concentrations at measurement locations in 2015, and the model root mean square error.

NO_2 monitoring site	Measured NO_2 annual mean concentration 2015 (µg.m^{-3})	Modelled NO_2 annual mean concentration 2015 (µg.m^{-3})
DT33	46.9	39.7
DT44	27.1	26.8
DT45	32.1	30.4
DT56	29.6	22.0
DT58	48.3	41.7
DT81	35.3	36.5
DT82	23.8	23.4
DT85	22.4	19.5
DT86	34.9	24.5
DT96	31.1	30.5
DT97	30.5	29.4
DT98	25.4	22.9
DT99	29.8	35.2
DT100	28.9	23.5
DT106	29.4	31.3
DT107	30.7	29.0
DT111	21.3	19.6
DT112	27.1	21.9
DT119	27.7	32.2
DT124	22.5	18.7
DT126	36.0	37.9
DT128	29.6	21.4
DT129	31.5	34.4
DT130	35.2	35.3
DT131	39.5	35.6
DT133	31.9	35.8
DT139	29.4	26.1
DT140	36.3	27.7
DT141	32.3	24.1
DT143	38.2	38.6
DT144	37.2	38.2
DT145	29.9	35.5
DT146	26.6	25.5

NO_2 monitoring site	Measured NO_2 annual mean concentration 2015 (μg.m^{-3})	Modelled NO_2 annual mean concentration 2015 (μg.m^{-3})
DT147	27.7	22.2
DT148	27.5	22.7
DT152	27.6	26.3
DT153	29.0	29.7
DT156	25.9	24.2
DT157	27.2	26.7
DT158	25.5	23.2
DT159	34.0	31.6
DT161	32.3	24.3
DT162	24.5	22.7
DT163	23.2	24.9
DT164	20.3	20.9
DT165	15.1	16.7
DT166	32.1	21.3
DT167	28.3	22.0
DT168	24.3	24.3
DT170	19.1	23.0
DT171	18.1	22.2
DT172	44.5	28.6
DT173	28.4	29.5
DT175	34.7	43.9
DT174	28.7	32.8
DT176	47.8	43.9
DT177	48.1	55.1
DT178	45.4	44.8
	RMSE (all sites)	**5.1 μg/m^3**
	Fractional Bias	**0.05**
	Correlation Co-efficient	**0.81**

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Analytical assurance statement

Analytical Assurance Statement for transport and air quality modelling.

1. Limitations of the Analysis
    - Has the Analysis been constrained by time or cost, meaning further proportionate analysis has not been undertaken?
    - Could the further analysis that could be done lead to different conclusions?
    - Does the analysis rely on appropriate sources of evidence?
    - How reliable are the underpinning assumptions?
2. Risk of Error / Robustness of the Analysis
    - Has there been sufficient time and space for proportionate levels of quality assurance to be undertaken?
    - Have sufficient checks been made on the analysis to ensure absence of errors in calculations?
    - Have sufficiently skilled staff been responsible for producing the analysis?
3. Uncertainty
    - What is the level of residual uncertainty (the level of uncertainty remaining at the end of the analysis)?

4. Use of analysis

    - Does the evidence provided support the business case?
    - Is there evidence the agreed target will be achieved?

1. Limitations of the Analysis

- *Has the Analysis been constrained by time or cost, meaning further proportionate analysis has not been undertaken?*

  The analysis has been constrained by time and cost to some degree. The city-wide modelling of transport and air quality of a range of options is complex and time consuming, and the project is working to a time and cost budget. However, we have made every effort to ensure that the analysis provided is as robust as possible within these constraints. This has included a thorough review of modelling assumptions and outputs within the consultancy team and with key stakeholders in the Council. In addition, a set of sensitivity tests to assess the robustness of the conclusions has been carried out and is discussed further below.

  A further piece of analysis is being carried out to assess the impact of each of the measures within the preferred CASAP.

- *Could the further analysis that could be done lead to different conclusions?*

  Given the level of review by external stakeholders and sensitivity tests that have been carried out, we do not believe that further analysis would lead to different conclusions. The further analysis being carried out at the individual measure level will purely provide more detail on the contribution of individual measures rather than change the outcome or conclusions.

- *Does the analysis rely on appropriate sources of evidence?*

  The work has aimed to use the most appropriate data sources that could be collected within the time and budget available. The key data sources comprise:

    - Traffic flows and speeds have been provided by the existing South East Wales Transport Model (SEWTM) which has been built, calibrated and validated in accordance with WebTAG guidance, as detailed in the Local Model Validation Report (LMVR), Demand Model Report, and Forecasting Report. These reports illustrate a close fit between the model and observed data sources, as well as sensible responses falling within expected WebTAG ranges in realism testing. The model has been built using local data where possible (including mobile phone data used to develop base year demand matrices), and has been used on a wide variety of studies since its completion in 2017.
    - The data used to build, calibrate and validate the SEWTM includes household travel surveys representing local travel preferences, and count data collected specifically for the transport model. Observed signal timing data has been used to develop the coding of the highway networks, which feature detailed junction modelling across a large area including the Cardiff Local Authority. Calibration and validation of the highway model includes comparisons of flows on both links and turns, for cars and all vehicles, as well as comparisons of modelled journey times with observed data from TrafficMaster. A particular focus has been applied to the urban areas of Cardiff and Newport, and count sites used for comparisons with the model are situated more densely in these locations.
    - Local fleet composition data was derived from an analysis of a comprehensive ANPR survey covering the AQMA's and PCM exceedance roads in the city over a one-week period in May 2018. This has been used to provide both compliant/non-compliant split in the traffic model and the detailed fleet split in terms of Euro standards in the air quality emissions model – see section 4.3.2 in the air quality modelling methodology report for further details.
    - Vehicle emission data is based on COPERT V as specified by the JAQU guidance and again is consider the best available data for this scale of modelling.
    - Ratified diffusion tube and automatic site monitoring data for 2015 have been used to validate the air quality model and were available at some 65 sites across the city. Both automatic sites and diffusion have been used for model validation, as the full set of sites gives good coverage and robust statistics across the whole modelled area.

- *How reliable are the underpinning assumptions?*

  There are a wide range of assumptions used in the transport and air quality modelling and economic assessment work. In general, the study has used the assumptions as provided by JAQU guidance for carrying out the CAZ feasibility studies. However, there are a number of areas where local assumptions have needed to be made and the evidence for these assumptions varies.

  The key assumptions considered that are likely to have the most impact on the analysis are summarised as follows:

    - Transport modelling – SEWTM has been used to determine the traffic flows and speeds for the baseline, and the traffic impacts of each of the transport schemes being considered. The key assumptions used in the traffic modelling include:
        - Underlying demand model parameters have been developed from household travel survey data to better represent the travel patterns of the local population, including localised representations of Values of Time (VOT). These localised VOT values are also used in the highway assignment model, with WebTAG databook values used to represent Vehicle Operating Costs (VOC). Demographic information for the base model is adapted from Census data and other ONS sources, with Experian data used to provide overall demographic growth at a Local Authority level for forecast years.

        - The 2021 reference case model development included the creation of a demographic scenario whereby growth was distributed to specific development sites based upon data provided by Cardiff Council, to better represent the distribution of traffic growth in the model. The highway model included all significant layout changes implemented between the base model year of 2015 and 2018, as well as likely schemes between 2018 and 2021. Additionally, the Keolis Amey rail 2021 scenario for the Core Valley Lines was implemented in the public transport component of the model as part of the process used to develop the reference highway demand. Growth in VOT and VOC parameters was derived from the May 2018 version of the WebTAG databook, which was the latest version available at the time of the modelling. The Department for Transport's Road Traffic Forecasts 2015 data was used to account for growth in goods vehicle and external trips. The 2018 update to this data has since been published, but project timescales have meant it has not been possible to incorporate this data into the modelling. Greater detail on the assumptions made to develop the 2021 reference case model can be found in the transport model methodology report.
        - The compliant and non-compliant split in the transport model was based upon data from ANPR cameras installed temporarily at 12 locations in Cardiff, covering 21 traffic movements. Splits were applied at a whole model level. Some consideration was given to implementing different splits based upon location, but owing to practical difficulties and only small differences between ANPR sites this was not implemented. Splits were however implemented based on a volume weighted average across the sites.
        - The assessment of the FBC measures has been carried out as fixed demand with respect to the city centre schemes (as opposed to using the full variable demand model), primarily due to challenging project timescales but also due to practical issues regarding the availability of data regarding taxi trip patterns. This is discussed in further detail below.
    - Fleet projection – it has been necessary to project the 2018 ANPR fleet data forward to the target year, and backward to the 2015 modelled base year. This has been done with a fleet project tool developed by Ricardo. This takes as its basis that the local trends in fleet turn over will be the same as the national data in the NAEI, but from a different starting point. This is clearly a simplification and there are likely to be some differences locally. However, given no local projections exist, this was viewed to be the best approach and in-line with JAQU guidance.
    - CASAP measure assumptions – the details behind the assumptions used to model the CASAP scenario are set out in detail in the transport and air quality methodology reports. The assumptions and uncertainties can be summarised as follows:
        - Overall the behaviour/activity assumptions used are based on existing information from key stakeholders involved in implementing these measures.
        - With the introduction of electric buses on routes 27, 49/50 and 44/45, it was assumed that all buses servicing these routes would be electric (comprising the 36 buses). An estimate was then made of the proportion of bus flows allocated to these services along any given road link and then these flows removed as they are now zero emission.
        - For the retrofit programme it was assumed that there would be 80% uptake in the bus fleet (of those that were non-Euro VI) to reflect that not all operators would be willing to participate in the scheme. A sensitivity test was then carried out for the impact of this uptake dropping to 50%.
        - The impact on the taxi fleet of a 10-year age limit (with Euro 6 renewal requirement) was a simple manipulation of the fleet and cross-checked with the taxi licencing department. There was no data available on the likely uptake of grants for ULEV taxis, so it was assumed that uptake would be 5% for hackney cabs and 20% for PHV's based on a consideration of the price of ULEVS vs a Euro 6 diesel renewal. A sensitivity test was then carried out that assumed no uptake of the ULEV grants. All ULEVs were assumed to be zero emission.
        - The impact of the active travel measures (CS1 and the 20mph zones) was assessed in the transport model with the assumption that there would be a

    3% reduction in trips with an origin in the areas affected by the schemes. This assumption was based on the impact of previous schemes of this nature implemented in Cardiff. A sensitivity test was carried out which reduced this assumption to a 1 % mode shift.
    - The impact of the city centre schemes was assessed in the transport model, using details of the schemes in terms of road closures, lane removals and signal timing changes. The methodology was designed to take some account of different movement restrictions for taxis, which form a high proportion of vehicles in the area surrounding the schemes. SEWTM, as with the vast majority of transport models, does not include explicit representation of taxi movements, for which data is rarely available. As such, this can only be considered as a proxy approach. Nevertheless, this is likely the best approach that could be achieved with the time, budget and data available.
    - As noted above, the modelling of the city centre schemes was carried out on a fixed demand basis with the only allowed response as rerouting. The fact that SEWTM covers an area wider than Cardiff means that the full effect of the resulting rerouting is captured within the modelling. However, the effects of mode, destination and time of day switching resulting from these schemes is not modelled. Including these effects in the modelling would likely result in a reduced level of car demand in the city centre overall, meaning that the current approach is conservative in terms of the air quality benefits likely to result from the schemes. Additionally, a reduced level of demand in the city centre would likely result in a reduction in the time related disbenefits, meaning that the approach is also conservative in terms of the economic assessment. A sensitivity test has been carried out using the elasticity method and shows a modest decrease in both city centre traffic and the economic disbenefits. This is, however, a crude methodology which cannot represent a number of the effects that could be modelled using a full Variable Demand Model (VDM) run. As such, more detailed work under a longer timeframe would likely show improvements in both the forecast vehicle emissions and the economic assessment.
- The city centre charging scheme assumptions - the key assumption used here is in relation to the upgrade behaviour of drivers in relation to the charge. The standard behavioural responses provided by JAQU, based on TfL data, have been used as the basis. However, since lower charges were proposed for Cardiff a linear relation between price and response was used to derive the responses used in Cardiff. This was based on a review of the stated preference work on London for the ULEZ that suggested a linear response was likely for light duty vehicles. It is also recognised that in practice the response may be different in Cardiff but given that the charging scheme is unlikely to be progressed it was felt that adopting the JAQU assumptions was a proportionate approach within the time and resource available. It should be also noted that mode shift and trip cancelation responses were implemented in the traffic model as matrix adjustments, unlike the city centre schemes where no account was made of these responses.
- Impact extrapolation – to provide the economic assessment over a 10-year period an estimate of the benefits and costs over 10 years needs to be made. Generic guidance has been provided by JAQU on this topic and we have taken this into account in developing the approach for this study. The key elements that needed to be extrapolated were single year emission benefits and TUBA results.
    - To extrapolate the emission benefits without modelling further future years at this stage it was felt to be proportionate to model the reduction in emission benefit of the scheme using the PCM trends from 2020 to 2030 for the Cardiff baseline PCM results. We recognise that this does not account for a number of local factors, not least future development and highways schemes. However, this approach was deemed appropriate and most proportionate given the time and resource available.
    - For the extrapolation of the TUBA results factors have been calculated to apply to single-year benefits, based upon WebTAG Unit A1.1: Cost Benefit Analysis. These factors account for the effects of:
        - Time-related discounting;

- Changing values of time (for VoT-related benefits only); and
- Demand growth.

In summary there are limitations and uncertainties in the assumptions made but we feel that what has been done is proportionate the for time and budget available to provide a robust evidence base for the final preferred option.

2. Risk of Error / Robustness of the Analysis

- *Has there been sufficient time and space for proportionate levels of quality assurance to be undertaken?*

Quality management for all Ricardo and Motts projects (and all deliverables produced) is delivered in accordance to the requirements of the International Standard ISO 9001:2008. Principles of quality assurance (QA) are integrated in all our activities and at all levels through established and implemented procedures according to the international standard. The formally appointed Project Manager and Project Director lead in ensuring the project is undertaken in accordance with the current Ricardo and Motts Quality Assurance processes and that the system is effective.

As noted above the citywide modelling of the CAZ options is both complex and time consuming, whilst being carried under tight delivery times scales. However, all analysis for Cardiff (transport, air quality and economic) has been developed in accordance with these over-arching Ricardo and Motts QA policies and procedures to ensure high quality and accuracy of deliverables. Specifically, this includes:

- Use of the core principles from our modelling QA group in the design of analysis spreadsheets;
- Technical oversight of methodological modelling issues from our modelling and economics knowledge leaders;
- Day-to-day oversight of the modelling work by the lead modeller;
- Checks of assumptions, input data, calculation sheets and output results
- Overall review and sign off by the project director.

All models have been developed in accordance with Ricardo's 'best practice' modelling guidance for the construction of workbooks and tools. This includes having separate sheets for data import, manipulation and results. In addition, the model has been developed with strict version control procedures (to avoid version error) and with assigned governance and responsibilities (i.e. the PM holds overall responsibility for the quality of the model, with analysts holding joint responsibility for the elements they developed).

In some cases, some data transformations have been carried out in MS Excel prior to import to the economic model. Each of those transformation workbooks has been identified and subject to scrutiny.

All data sources used in the model are appropriately referenced and clearly marked where data is inputted into the model. All assumptions and data sources have been logged, as part of the Air Quality and Economic Methodology Reports.

In addition, for this specific work additional QA checks have been performed with the input of Cardiff Council and the wider consultancy team. For example, where data and assumptions have been drawn from external models, we have discussed directly our interpretation of the data received, and its planned use in the economics model to sense check our approach (e.g. air quality emissions outputs, and transport modelling outputs).

Mott MacDonald transport modelling projects are carried out under the company's modelling best practice guidance, which is updated continually with advances developed internally and within the wider transport modelling community.

In accordance with Ricardo's and Motts QA processes, all deliverables and outputs have been signed off by both the Project Manager and/or Project Director before release. Also, where time has allowed we will issue draft results to Cardiff to allow the city to review and scrutinise results prior to finalising.

- *Have sufficient checks been made on the analysis to ensure absence of errors in calculations?*

  Checks on modelling work are carried out as part of our quality assurance process. Again, with complex models across several thousand road-links there is a large amount of data and calculations to check. With this amount of data it is not possible to check everything. Our approach has been as follows:

    - Review and check all methods being used in the model set up and calculations;
    - Review model input data for consistency, this has focused on samples of data and key locations;
    - Check calculations in all spreadsheets, again using a sampling approach to check calculation steps;
    - Sense check results using the experience of the lead modeller, knowledge leader and project director to ensure that they seem reasonable.

  A log of all checks carried out is kept and where any anomalies in results have been identified in the checking process these have then been explored for errors in data or calculations, and corrected as necessary.

  Finally, as part of the model validation process for the base year air quality model the results are compared with monitoring data. Where there is a significant difference with the modelling data, + or – 30% checks are carried out to explore why these differences occur.

  We believe this level of check is proportionate for the time and resources we have available, and has identified a number of issues that have had to be corrected. However, it is not an absolute guarantee that there are no errors, but it is sufficient to ensure that all results are reasonable and consistent.

- *Have sufficiently skilled staff been responsible for producing the analysis?*

  The air quality modelling team at Ricardo have significant experience of developing, assessing and recommending measures to reduce emissions and improve air quality at the city scale, including extensive expertise in air pollution modelling from the development of inventories and baselines to modelling the future impacts of abatement scenarios.

  The team is led by a Project Director who holds over 20 years of experience of working on transport and emissions reduction projects. His key areas of expertise include vehicle emissions modelling, low emission vehicle technologies, sustainable transport measures and local air quality management and policy and he has worked on a number of LES, LEZ and CAZ projects in the UK including in Southampton, Derby, Nottingham, Oxford, London, Leicester and South Oxfordshire.

  The day-to-day modelling work is led by an experienced atmospheric scientist with a strong focus on modelling transport and industrial emissions and characterising their effects on ambient air quality who is an advanced user of ADMS, ADMS-Roads, ADMS-Urban, AERMOD, ArcGIS, and QGIS.

  The modelling lead is supported by our modelling knowledge leader, who developed our RapidAir and RapidEms models, to explore and resolve any methodological issues. In addition, a team of experienced consultants specialising in air quality impact assessment and atmospheric dispersion modelling are carry out aspects of the modelling work, guided by the modelling lead. All staff have had specific training on all the modelling tools being used for this work.

Mott MacDonald have extensive experience in the development and application of strategic transport models and local highway models. The team responsible for the development of the air quality transport models includes several of the main individuals behind the original SEWTM build (upon which this study has been based) and have been behind its successful application on a wide range of studies since the model's completion.

The Birmingham based team has also been responsible for the development and application of the West Midlands PRISM model since its inception and represents one of the most experienced sets nationally of VISUM users, the software package in which the assignment models have been built.

The transport model project leader is the manager across all SEWTM applications and ongoing model development and has led modelling contributions towards a number of projects in the South East Wales region.

3. Uncertainty

- *What is the level of residual uncertainty (the level of uncertainty remaining at the end of the analysis)?*

The level of uncertainty included within the transport modelling is only estimated in the base year model as part of the validation process comparing the modelled and observed data. The validation of the highway assignment model includes comparisons between modelled and observed values of vehicle flows for links and turns for cars and all vehicles, as well as comparisons of modelled journey times against observed TrafficMaster data. The model shows a strong fit to counts as defined in WebTAG and detailed fully in the LMVR. A particular focus has been placed upon validation in the Cardiff Local Authority area as one of the most crucial areas of the model. The spread of count sites used for comparisons are denser in this location. Modelled trip length distributions have also been shown to match closely with observed data.

In addition to the comparisons described above, the model has undergone realism testing for the purposes of checking its response to changes in travel costs. Modelled responses have met the requirements set out in WebTAG.

A direct assessment of uncertainty in the air quality results is also only carried out for the baseline model as part of the validation process against monitored air quality data and essentially indicates the overall uncertainty in the transport and air quality models. In this process model performance and uncertainty is assessed using the Root Mean Square Error (RMSE) for the observed vs predicted NO_2 annual mean concentrations, as detailed in Technical Guidance LAQM.TG(16). In this case the RMSE was calculated at 5.1 $\mu g.m^{-3}$ which is typical for city scale modelling of this nature. This can then be used as a measure of error on forecast results for future years. This error metric has been used when considering the results by identifying locations over 35 $\mu g.m^{-3}$ as being at risk of exceedance.

However, when assessing options in future years there will also be uncertainty related to the assumptions we have made in modelling these options. The reliability of the assumptions used in the modelling has been discussed above and has been tested through sensitivity tests. The key outcome of these tests are as follows:

    - Lower performance of Euro 6 – this was tested for the baseline and preferred CASAP options by setting all light duty vehicles to base Euro 6. This increased concentrations in 2021 by between 1.3 and 3.3 $\mu g.m^{-3}$ with an average 2$\mu g.m^{-3}$. This increased the exceedance on Castle Street from 41.1 $\mu g.m^{-3}$ to 44.4 $\mu g.m^{-3}$ but did not generate any new exceedances. The impact of this test on the preferred CASAP option was to increase the concentration on Castle Street to a maximum of 35.2 $\mu g.m^{-3}$ still well under the compliance limit value.

- Lower fNO_2 by 40% - this was again tested for both the baseline and CASAP options and significantly reduces concentrations by between 1 and 5 µg.m^{-3}. This removes the exceedance on Castle Street and would only serve to improve the outcome of the preferred CASAP option.
- CASAP low test – this test used more pessimistic assumptions for the CASAP scenario measures as discussed above including only a 50% uptake of the bus retrofit programme, no uptake of the Taxi ULEV grant and a lower mode shift of 1% for the active travel measures. This increased concentrations from between 0 and 3 µg.m^{-3}, with the result on Castle Street increasing from 31.9 µg.m^{-3} to 34.6 µg.m^{-3}. If this test is combined with the worst-case impact of the Euro 6 test the result on Castle Street would increase to a maximum of 37.9 µg.m^{-3} so is still achieving the limit value.

This indicates that the preferred CASAP package is robust under the sensitivity tests carried out, in terms of its ability to achieve compliance.

4. Use of analysis

- *Does the evidence provided support the business case?*

Evidence in relation to the primary success factor has been provided from the analysis in terms of NO_2 concentration results for each of the national model road links in Cardiff, for the baseline and each of the tested options in 2021. This is complemented by a cost benefit analysis and distributional analysis for each of the tested options.

This analysis indicates that the key compliance issue that remains to be solved in 2021 under the baseline scenario is on Castle Street. Two mitigation options have been assessed in the FBC that solve this compliance issue:

- *A package of Clean Air Strategy Measures (CASAP)* – this combines a package of city centre traffic restrictions, with improvements to the bus and taxi fleet and a package of active travel measures. The assessment indicates a significant improvement of NO_2 concentrations on Castle Street to 31.9 µg.m^{-3} which then comfortably achieves compliance. The average improvement across all PCM links is 2 µg.m^{-3} with the maximum improvement being on Castle Street.
- *The city centre car-based charging scheme (CAZ 1)* – which has been modelled as an alternative to the CASAP option. This option is also modelled to achieve compliance on Castle Street achieving a maximum concentration of 32.5 µg.m^{-3}. However, the overall impact of this scheme is less than the CASAP scenario with an average improvement across the PCM links of only 1 µg.m^{-3} with some links showing an increase due to traffic diverting to avoid the scheme.

The sensitivity analysis carried out on the transport and air quality models indicated that the both the CASAP and CAZ 1 schemes were robust in achieving compliance even when the underlying assumptions were flexed.

The distributional analysis further illustrated the wider air quality benefits that the CASAP option produces compared to the CAZ 1 charging scheme. The CASAP options shows greater reductions in average NO_2 concentrations across the city and for all sensitive receptors than the CAZ 1 option. The analysis also indicated that low income and disadvantaged groups would gain the most benefit from air quality improvements with the CASAP option. The CAZ 1 charging scheme had the greatest impact in terms of household affordability due to the charges on non-compliant vehicles, and although these costs fall most on the higher income population, as they travel more into the city centre, the impact would be proportionally greater on low income groups who have more older vehicles.

Both of the schemes suffered traffic impacts in relation to vehicles diverting to avoid the city centre restrictions or charges. This reduces traffic in the city, the main target for air quality improvements, but has some increases elsewhere. For the CASAP scenario this has also resulted in increased travel times for some groups. However, the true scale of this is uncertain as the modelling only considered assignment and not the possibility of mode shift.

Value for money assessment of the options through the cost benefit analysis showed that both schemes have a negative NPV (the costs outweigh the benefits), with the CASAP scheme having the most negative NPV. The negative NPV for the CASAP option is dominated by the travel time disbenefits due to traffic diverting to avoid the city centre restrictions. However, as noted above the travel time delays are uncertain due to the limitations of the modelling and are likely to be reduced is full variable demand modelling was carried out. The dominate factor in the negative NPV for the charging scheme are the user charges themselves.

An important point in the CBA is the positive health benefits of the CASAP option in terms of improved air quality (£4.8 million benefit) and active travel benefits (£15 million benefit). In comparison the CAZ 1 option indicates an overall negative health benefit as air quality is worsening in some areas, which is counter to the overall objective of reducing air pollution to improve public health, and it does not generate any active travel benefits.

Overall the evidence suggests that the CASAP scheme should be taken forward as the preferred option because:

- It achieves compliance by the greatest margin and is robust under the sensitivity tests carried out.
- It generates the greatest health benefits from both air quality improvements and active travel benefits, compared to the CAZ option which in fact generates an overall health disbenefit.
- The benefits generated by the CASP option fall most to low income and disadvantaged groups which supports wider social goals.
- Although the NPV is worse for the CASAP option the dominate factor driving the negative NPV is associated with some uncertainty. Also, the legal ruling in relation to compliance sets out that costs are not a material consideration in terms of achieving compliance as soon as possible.

- *Is there evidence the agreed target will be achieved?*

The current results show that both the CASAP and charging CAZ options can achieve compliance and that this is robust in relation to the sensitivity tests carried out.

Technical Note

Project:	Cardiff Clean Air Feasibility Study		
Our reference:	367590	**Your reference:**	-
Prepared by:	George Bate	**Date:**	05/06/2018
Approved by:		**Checked by:**	Philip Old
Subject:	Final Business Case Transport Modelling Technical Approach		

This technical note outlines the transport modelling work undertaken by Mott MacDonald to develop the evidence base for the Cardiff Clean Air Feasibility Study Final Business Case (FBC). This report is limited only to the specific measures selected for the FBC.

1 Introduction

This technical note provides information only on the testing of the measures selected for the FBC and does not include background information on the South East Wales Transport Model (SEWTM), reporting on the preparation of the 2021 reference case forecasts, derivation of engine-type splits, or testing of previously considered transport interventions. Reporting on these items is presented elsewhere.

Final Business Case Interventions

The interventions selected for the Cardiff Clean Air Feasibility Study FBC are a revision of the Clean Air Strategy Package (CASAP) interventions tested at earlier stages of the study and do not include either of the Clean Air Zone (CAZ) options previously modelled.

The FBC transport interventions can be divided into two broad categories:

- Active travel packages; and
- Highway network changes in the city centre.

There are a number of newly introduced vehicle movement restrictions incorporated within the highway network changes which apply to general traffic but not to Hackney Carriages or Private Hire Vehicles (referred to henceforth as “taxis”). Due to a high proportion of such vehicles in the city centre it has been necessary to separate out some components of taxi demand in order not to overstate the changes brought about by the schemes in terms of both air quality and economics.

FBC transport interventions have been assessed using the 2021 baseline as a starting point and applying highway network and trip matrix adjustments using methods set out in Table 1 below, and in greater detail later in this note.

The same transport model outputs as in previous stages of this study have been provided to Ricardo for the purposes of assessing the air quality impacts of the FBC.

Table 1: Clean Air Strategy Package Intervention Methodologies

		Description	Modelling Methodology	
Active Travel	1	Active travel packages, covering two areas close to the city centre	For each of the locations a 3.5%-point reduction in the car driver mode share was assumed for trips entirely within the given area, and the car vehicle demand matrices adjusted accordingly	
	2	Cycling programme to end of 2020, covering a corridor north from the city centre		
Highway Alterations	3	Westgate Street mid-point closure to general traffic	The central section of Westgate Street was closed to cars and goods vehicles to prevent through-movements whilst maintaining local access.	Some exceptions were made to allow taxis to carry out movements now banned to general traffic as part of the Westgate Street and East Side Schemes. Additionally, updated signal timings for a number of junctions in the city centre were adapted from a micro-simulation model developed by AECOM, in order to account for the change of movements in the area.
	4	East side scheme, reducing through traffic movements on Station Terrace	Links were opened/closed as appropriate and junctions edited to reflect the proposed scheme.	
	5	Castle Street Scheme	Link capacities were reduced and junction layouts edited to account for the removal of traffic lanes on Castle Street.	

Source: Mott MacDonald

Technical Note Structure

The remainder of this note is structured as follows:

- Section 2 sets out the methodology used to extract taxi movements from the demand matrices.
- Section 3 sets out the methods used for assessing transport interventions on the highway network.
- Section 4 describes a sensitivity test undertaken to show air quality compliance is achieved under more conservative assumptions.
- Section 5 describes the steps undertaken to develop an economic assessment of the transport interventions using the TUBA (Transport User Benefit Appraisal) software.
- Section 6 describes an elasticity test used to estimate the impact of assessing the FBC measures with fixed (rather than variable) demand measures.

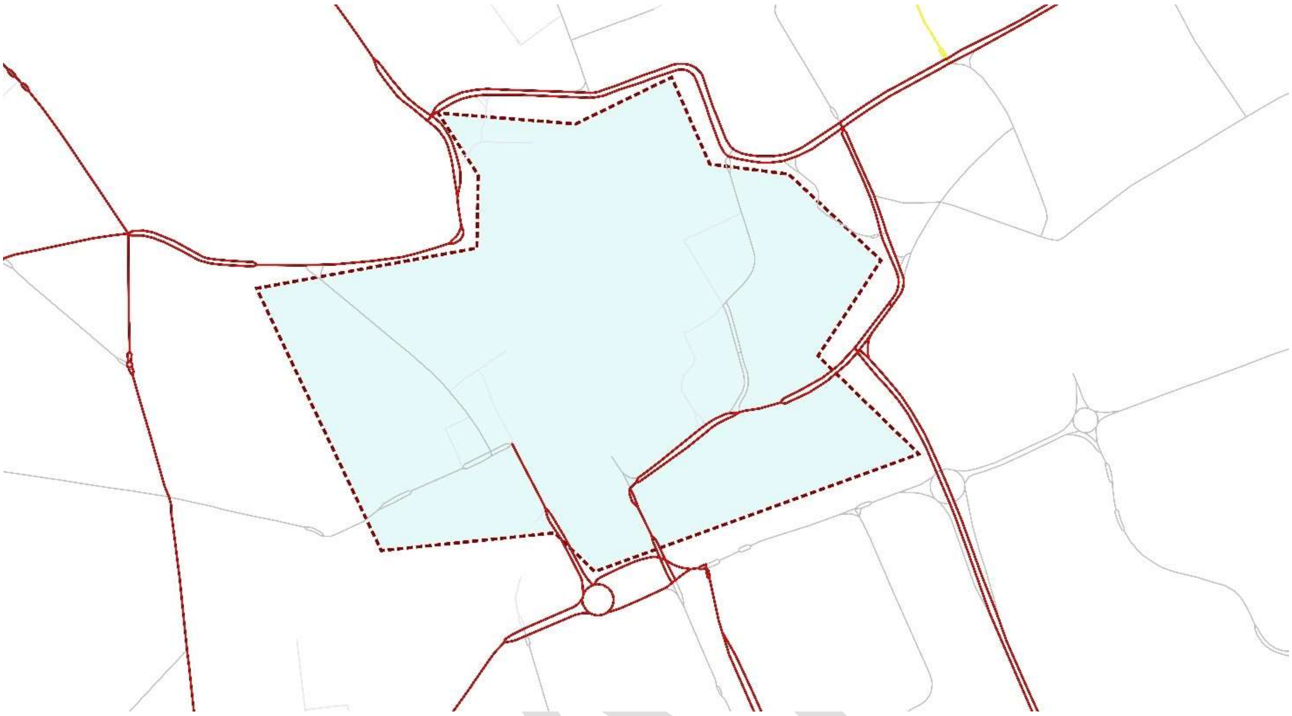
2 Taxi Demand

This section details the methodology used to identify taxi demand for certain movements, for which movements around the city centre are less restricted by the highway network interventions.

Background

In previous runs of the transport model, taxi demand has been modelled as part of general car demand, with no consideration given to differing travel patterns (this is the case with the vast majority of all transport models, primarily owing to a lack of data available to model taxi travel independently). In the air quality model separate zones have been defined within which a given percentage of taxi demand is assumed, based on ANPR data collected in May 2015. This is to allow the differing emissions characteristics of taxis to be modelled. Within this framework, discontinuities exist at the edges of zone boundaries whereby the number of taxis on consecutive links do not match. One such zone covers an area slightly larger than that in which the exceptions for taxis will apply, as shown below in Figure 1. Within this zone, 48% of the demand is assumed to be modelled as taxi, with a figure of 9% modelled immediately external to it.

Figure 1: Central Taxi Proportion Zone



Source: Mott MacDonald

Enabling Taxi Exceptions

The movements which under the scheme will be allowed for taxis but banned to general traffic are all currently allowed for all vehicles (the detail of these is discussed below in Section 3). An analysis of the vehicles making these movements has been undertaken in the baseline scenario to extract the number and origin-destination matrices of these trips. Of the total extracted demand 48% is assumed to be allowed to make these movements, as shown below in Table 2. Note that this assumes that no taxis will divert from alternative routes to make these movements.

Table 2: Taxi Demand Extraction

Time Period	Total Hourly Demand for Relevant Movements	Taxi Hourly Demand for Relevant Movements
AM	1529	730
IP	1185	566
PM	1325	632
OP	386	184

Source: Mott MacDonald

New taxi demand segments have been defined within the assignments, for which the relevant movements are allowed (see Section 3 below). The demand matrices for these segments have been defined as proportions of the extracted car business and car other demand matrices for the movements, to match the totals shown above in Table 2. It is assumed that none of the extracted demand comes from the car commute segment, since it is unlikely that these movements would be made by taxi.

3 Testing Transport Intervention Measures

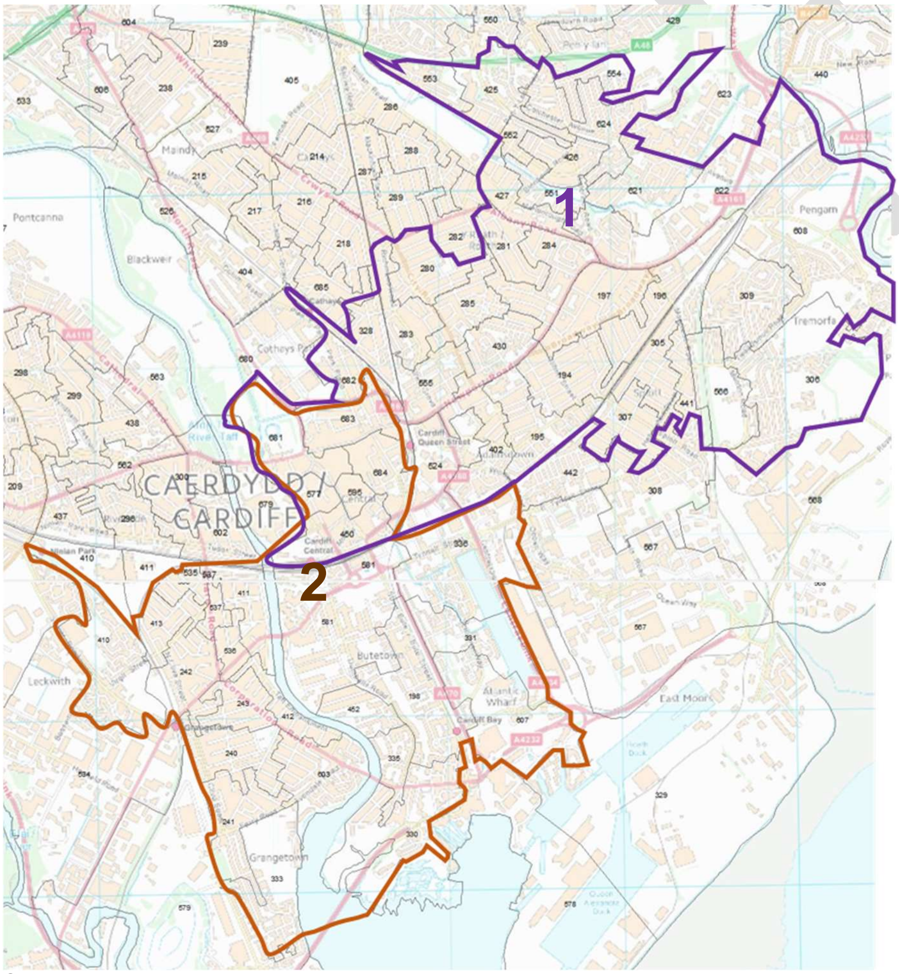
This section details the methodologies used to assess the impact of the final business case transport interventions on the transport network.

Active Travel Measures

Active travel package measures were modelled using evidence provided by Cardiff Council from a similar scheme already implemented around the Cathays Terrace area. Based on this evidence the active travel packages are assumed to lead to a 3.5%-point reduction in car driver mode share for car trips entirely within each of the two areas shown in Figure 2, with a single reduction factor applied across all trip purposes.

The forecast car driver mode share (without the active travel packages) was extracted from the synthetic highway matrices (a type of demand model estimate of trip making covering all modes, including walk and cycle) for the two areas. A reduction factor was then calculated based on the number of car trips that a 3.5%-points reduction equates to in each modelled time period. This reduction was applied to the car vehicle trip matrices for each journey purpose and engine compliance type.

Figure 2: Active Travel Package Areas



Source: Mott MacDonald

Reduction factors were applied to area 1 first. OD pairs included in the application for area 1 were then excluded from the analysis and application of area 2 (to avoid double-counting). Mode shares (prior to the implementation of the measures) and active travel package reduction factors are shown for areas 1 and 2 in Table 3 and Table 4 respectively.

Table 3: Area 1 Car Driver Mode Share and Reduction Factors

	AM	IP	PM	OP
Car Driver Mode Share	48.9%	60.5%	55.6%	54.1%
Factor Applied	0.93	0.94	0.94	0.94

Source: Mott MacDonald

Table 4: Area 2 Car Driver Mode Share and Reduction Factors

	AM	IP	PM	OP
Car Driver Mode Share	46.9%	60.1%	53.6%	53.3%
Factor Applied	0.93	0.94	0.93	0.93

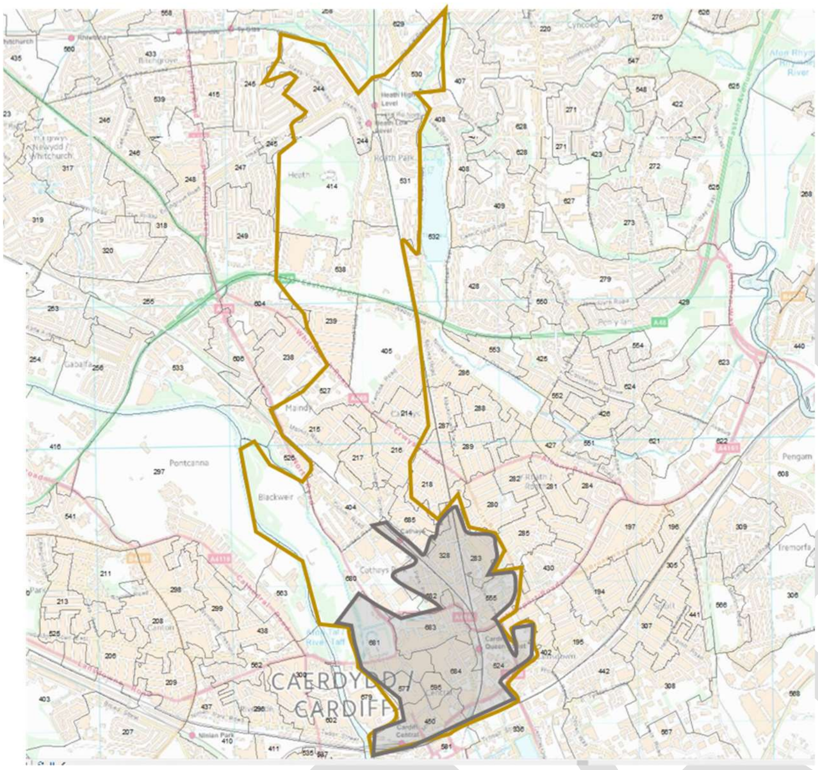
Source: Mott MacDonald

Cycling Programme to End of 2020

Similar to the active travel measure areas, a 3.5%-point reduction in the car driver mode share was assumed for trips entirely within the Heath to city centre corridor, which is to be covered by cycling facility improvements (shown in Figure 3). OD pairs entirely within the area covered by the previous active travel measures (shown in grey) were excluded from the analysis to avoid double-counting.

Other cycling programme proposals for the Newport Road and Cardiff Bay corridors were not included separately in the analysis, as the impact of these is assumed to be covered by the active travel packages.

Figure 3: Cycling Programme Area



Source: Mott MacDonald

Mode shares (prior to the implementation of the measures) and reduction factors are shown for the cycle package in Table 5.

Table 5: Cycle Package Area Car Driver Mode Share and Reduction Factors

	AM	IP	PM	OP
Car Driver Mode Share	50.4%	60.0%	55.7%	54.4%
Factor Applied	0.93	0.94	0.94	0.94

Source: Mott MacDonald

Westgate Street Mid-Point Closure to General Traffic

Through-movements for general traffic were prevented from using Westgate Street. Access to all city centre model zones has been maintained, although trips may need to re-route to avoid the closure. Exceptions were made for taxis. This is annotated in detail below in Figure 4.

Figure 4: Closure of Westgate Street

Source: Mott MacDonald

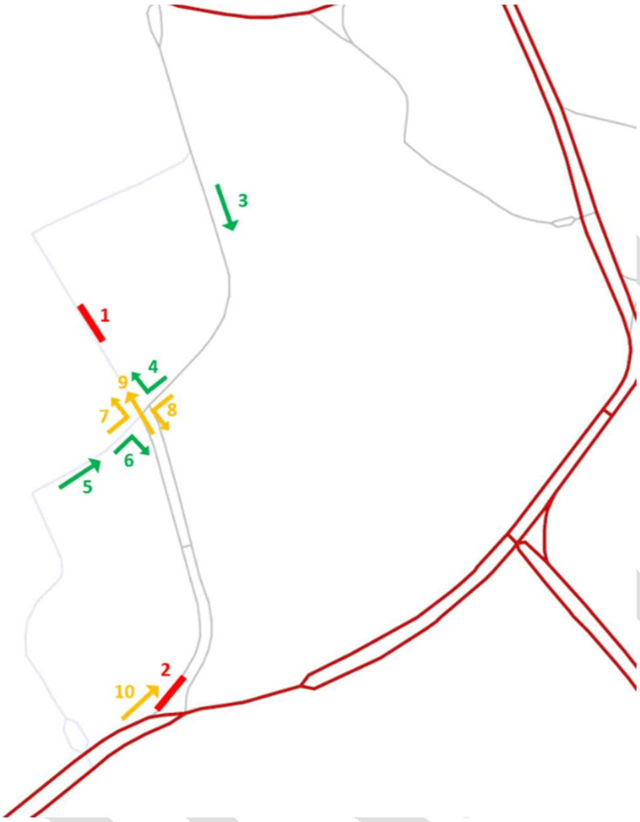
Annotations:

1. Closure of links shown to general traffic.
2. Compulsory right turn for general traffic from connector location onto Havelock Street.
3. Havelock Street northbound movement allowed for taxis only.
4. Northbound movement allowed for taxis only at southern end of Westgate Street, including straight on movement at the junction with Park Street.
5. Southbound movement allowed for taxis only at southern end of Westgate Street, including straight on movement at the junction with Park Street.
6. Turns between Park Street and the section of Westgate Street north of the Park Street junction allowed for taxis only. Turns between Park Street and the section of Westgate Street south of the junction are not allowed, even for taxis.

East Side Scheme

The highway network edits presented in Figure 5 were used to prevent through movements using Churchill Way, whilst allowing use of the affected roads for local access. Where signalised junctions were present, existing signal timings were maintained to account for bus and taxi movements.

Figure 5: East Side Scheme



Source: Mott MacDonald

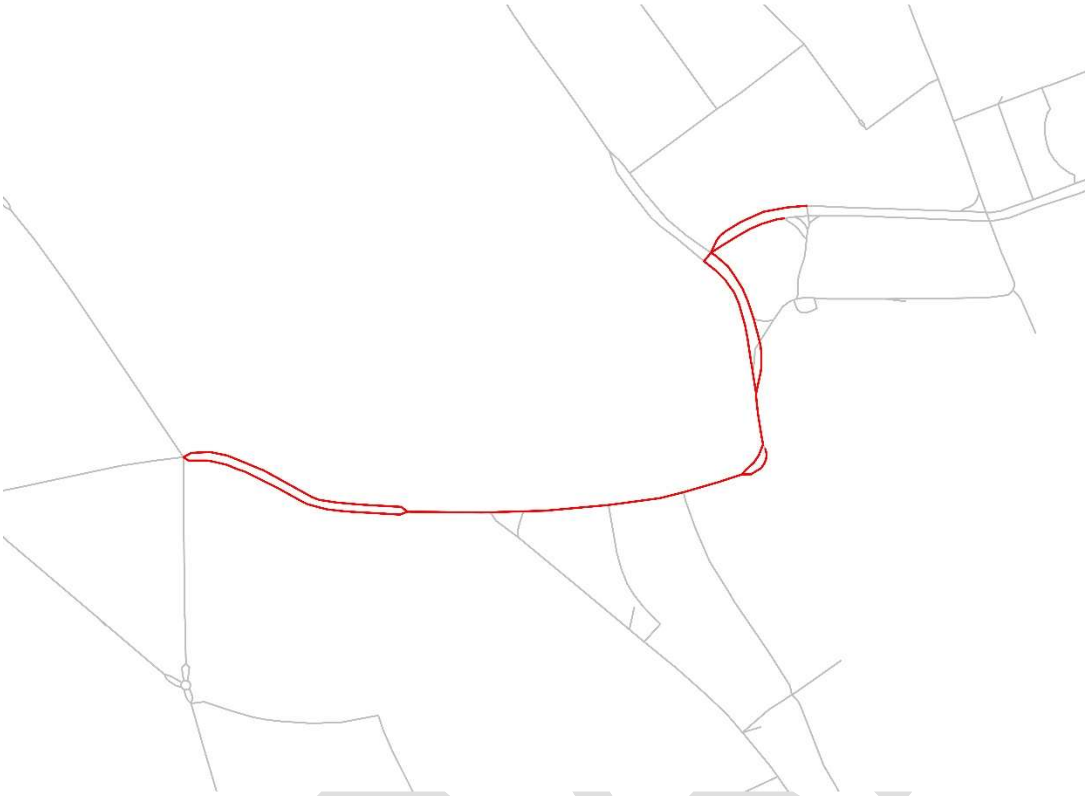
Annotations:

1. Closure of Churchill Way southbound between North Edward Street and Guildford Street.
2. Closure to general traffic of Churchill Way northbound at the entry from Bute Terrace.
3. Station Terrace/Guildford Street set to one-way southbound, south of North Edward Street only.
4. Mandatory right turn for general traffic implemented at signals for traffic from Guildford Street.
5. Bridge Street set to one way eastbound.
6. Mandatory right turn for general traffic implemented at signals for traffic from Bridge Street.
7. Left turn from Bridge Street allowed for taxis only.
8. Left turn from Guildford Street allowed for taxis only.
9. Straight on movement from Churchill Way allowed for taxis only.
10. Access to Churchill Way northbound from Bute Terrace allowed for taxis only.

Castle Street Scheme

The links indicated in Figure 6 below have had their number of lanes and capacities decreased in line with plans provided by Cardiff City Council. Where necessary junction layouts have been recoded to account for changes in the number of lanes and allowed lane turns in the plans.

Figure 6: Castle Street Scheme

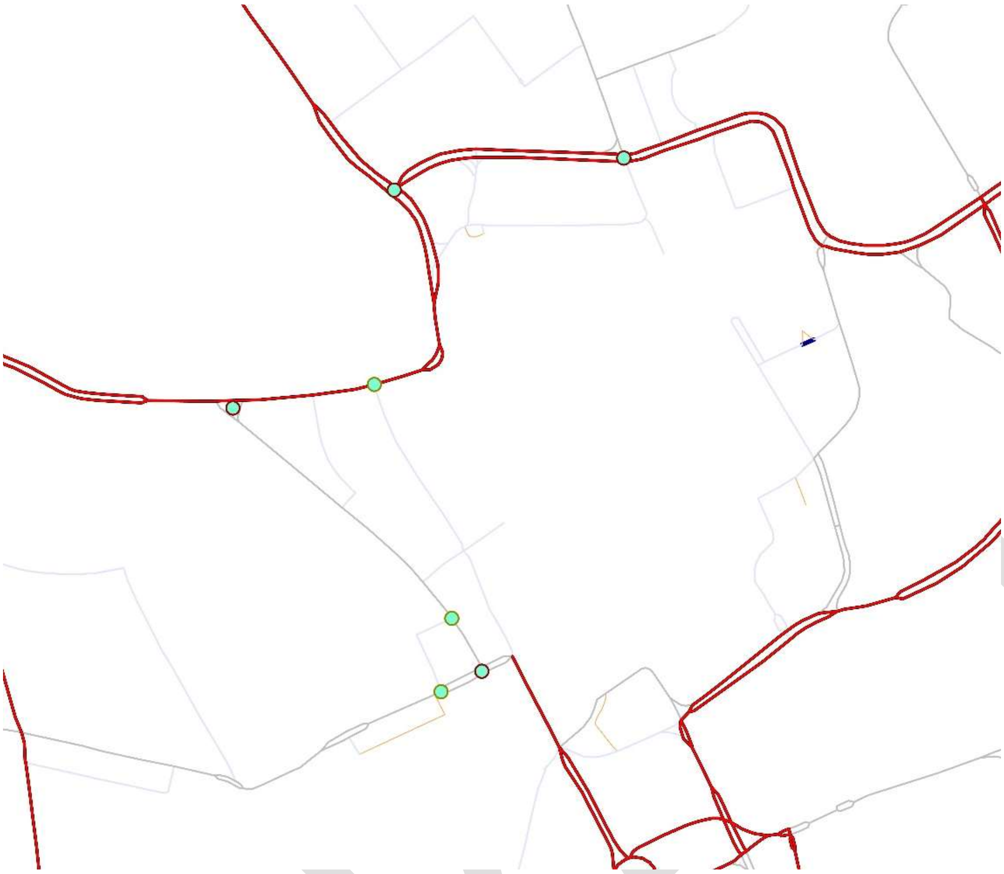


Source: Mott MacDonald

Signal Timings

Signal timings at the junction locations indicated in Figure 7 were updated in accordance with timings provided by AECOM from a microsimulation model developed by them.

Figure 7: Altered Signal Timings



Source: Mott MacDonald

4 Sensitivity Testing

A combined sensitivity test of the air quality and transport model has been carried out to check whether air quality compliance is achieved under more conservative (less optimistic) modelling assumptions. The alternative assumptions made within the transport model as part of this test are defined in Table 6.

Table 6: Sensitivity Testing Alterations

Measure	Standard Assumption	Sensitivity Assumption
Active Travel Packages	3.5% mode switch.	1% mode switch.
Cycling Programme	3.5% mode switch.	1% mode switch.
Westgate Street	Westgate Street closed to general traffic but open to taxis.	Westgate Street operated as within baseline scenario.

Source: Mott MacDonald

The same transport model outputs as in previous stages of this study have been provided to Ricardo for the purposes of assessing the air quality impacts of the sensitivity test. An economic analysis of this test has not been undertaken.

5 Economic Appraisal Using TUBA Software

TUBA Software

TUBA is the DfT's standard software tool for undertaking economic assessments of transport schemes and has been used to measure the transport-related impacts of the FBC measures.

The inputs required to run the software for a highway scheme are usually as follows:

- Economics text file. A standard version incorporating the latest WebTAG updates is supplied with the software.
- Scheme text file. A file defining various parameters related to the scheme(s) in question. Various example files are supplied with the software.
- Sector text file. A file relating model zones to sectors, used to disaggregate impacts by sector.
- Demand matrices by vehicle class/purpose in text file format for both do-minimum (DM) and do-something (DS) scenarios. Usually data for at least two modelled years is supplied.
- Generalised time cost matrices by vehicle class/purpose in text file format for both DM and DS scenarios. Usually data for at least two modelled years is supplied.
- Trip distance matrices by vehicle class/purpose in text file format for both DM and DS scenarios. Usually data for at least two modelled years is supplied.
- Toll matrices (if necessary) by vehicle class/purpose in text file format for both DM and DS scenarios.
- Reference distance matrices by vehicle class/purpose in text file format. These matrices are usually developed from base year assignments and are used to separate economic and other outputs by distance band.

The software produces a range of outputs, the most important of which are detailed below:

- Scheme output file. A text file with ".out" extension incorporating warnings related to skim values, input summaries, and outputs disaggregated by various attributes including distance band, time band, modelled year, user class, benefit type, and monetized/non-monetized values,
- Sectorized scheme output file. A csv file separating economic outputs by appraisal year, origin and destination sector, time period, user class, and benefit type.

The assessment has been carried out using the latest (v1.9.12) version of the software. The economics file has been adapted from the standard one supplied with this version of the software, which incorporates the November 2018 updates to the WebTAG databook. The FBC scenario has been compared to the 2021 baseline scenario. Implementation costs are accounted for elsewhere and have not been incorporated into the TUBA runs.

Main Edits to Economic and Scheme Files

Most parameters in the economic and scheme input files remain the same as those provided in the standard versions supplied with the software. However, edits of note have been made to account for the following:

- The standard economics file contains separate parameters for OGV1 and OGV2 vehicles. However, the SEWTM assignment is based a single combined HGV class. A separate HGV class has been created with parameters taken as a demand-weighted average of the standard OGV1 and OGV2 classes.
- An off-peak time period has been defined in the scheme file.
- Model-specific time periods and annualization factors have been defined in the scheme file. Annualization factors account for weekdays only. Weekends have been accounted for by Ricardo at the point of incorporating the transport modelling results into the rest of the economic case.

- Separate user classes have been defined for compliant and non-compliant engine standard vehicles. It is noted that whilst separate user classes have been defined for the purposes of disaggregating outputs by engine class, no distinction has been made between the parameters used for these vehicles in the economics file. This includes greenhouse gas production parameters.
- Separate user classes have also been defined for taxis to account for the difference in travel costs experienced by these vehicles in the FBC scenario. As with the separation into compliant and non-compliant vehicles, the same parameters have been used in the economics file for taxis as for non-taxi vehicles.

Accounting for Taxis

Taxis have been implemented in the FBC highway models as a separate assignment class to represent differences in available routing to other vehicles. However, this is not the case for the baseline scenario where there is no distinction between allowed movements for taxis and non-taxis. This means that the demand matrices fed into the TUBA for taxi movements for the baseline scenario are zero matrices and that here taxi demand is incorporated into the general traffic matrices. To produce a valid economic assessment, the general traffic skim matrices (for the relevant purpose/engine type) were used as the baseline taxi skims. This is because TUBA calculates user benefits and costs based on single user classes individually and requires skim costs even if a user class has no demand in a particular scenario. Note that this has no impacts on other impacts such as greenhouse gasses or indirect taxation since the fuel consumption (and other) parameters in the economics file are kept identical between taxis and non-taxis.

Running a Single Year TUBA

TUBA is set up to take inputs from two separate modelled years. This is so that benefits can be interpolated/extrapolated across the entire appraisal period. The clean air zone work has been carried out using a single modelled year of 2021. TUBA will not accept single year inputs to produce benefits for a multi-year appraisal period but will accept single year inputs to produce an appraisal for a single year.

To account for the entire appraisal period of 2021-2030 (inclusive), factors have been calculated to apply to single-year benefits, based upon WebTAG Unit A1.1: Cost Benefit Analysis (the methods described in this unit are the same as those employed within the software). These factors incorporate the effects of:

- Time-related discounting;
- Changing values of time (for VoT-related benefits only); and
- Demand growth.

The methodologies used to calculate demand growth are discussed below.

Adjusting Price Base and Discount Year

TUBA software usually uses a price base and discount year of 2010 to ensure consistency in assessing transport schemes. For the air quality work both a price base and discount year of 2018 are required. Whilst it is possible to edit TUBA inputs to account for this, it is considered simpler to account for these requirements using factors applied externally to TUBA economic outputs. The factors, calculated in accordance with WebTAG Unit A1.1 and the November 2018 version of the WebTAG databook, are shown in Table 7 below.

Table 7: Price Base and Discounting Adjustments

Adjustment from 2010 to 2018	Factor to be Applied to Economic Outputs
Discounting	1.317
Price base	1.142

Source: Mott MacDonald from WebTAG Databook, November 2018

Multi-Year Capitalization

As described above, demand growth has been incorporated into the factors used to convert single-year benefits. Per-annum demand growth across the appraisal period was calculated using the DfT's 2018 Road Traffic Forecasts (RTF) as shown below in Table 8. The data used was specific to Wales but averaged across all road types.

Table 8: Background Traffic Growth Rates

	Growth Across Period	Annual Growth
2020-2025	4.62%	0.91%
2025-2030	4.20%	0.83%

Source: Mott MacDonald from RTF 2018

The ultimate factors calculated to convert the single year FBC TUBA results to the ten year appraisal period are shown in Table 9 below.

Table 9: FBC Capitalisation Factors

Type	Factor
For use with all time-related benefits (incorporating value of time growth)	9.8
For use with other benefits (not incorporating value of time growth)	8.9

Source: Mott MacDonald

Whilst TUBA calculates monetized benefits across a wide range of transport-related impacts, there are various components which it has not been possible to take account of, either due to the limitations of the software or the modelling methodology. For the FBC measures these include:

- Health and journey quality for trips which switch to active travel resulting from measures 1 & 2;
- Generalized cost alterations for trips which switch to active travel, which are incorporated only as far as the "rule of a half" methodology outlined within WebTAG Unit A1.1;
- Parking charges and revenues which may change as a result from the same; and
- Various FBC measures which it has not been possible to incorporate into the transport modelling, such as fleet changes for buses to lower emission models.

6 Elasticity Testing

Reasons for Test

The results of the TUBA assessment of the FBC measures showed significant economic disbenefits, primarily related to increased congestion and travel times in the city centre. It is likely in reality that the disbenefits have been overstated for the following reasons:

- Several corridor improvement projects expected to alleviate the effects of reduced access to the city centre are at early stages and have not been considered in this assessment.
- The assessment has been carried out on a fixed demand basis and does not consider the effects of destination, mode, or time of day switching.

The elasticity test has been carried out to ascertain the potential scale of impact of the latter of these points. Whilst the demand response such as those in the FBC would usually be modelled using a full Variable Demand Model (VDM) run, there are several issues which have precluded this methodology in this instance:

- The requirement for splitting the assignment model into more disaggregate demand segments than would usually be used. The exceptions granted for taxis particularly represent an issue in this case due to a lack of data on taxi travel patterns.
- Consistency with other testing carried out to this point.
- The lack of time available to implement an additional VDM run.

Elasticity Methodology

WebTAG guidance specifies a range of realism tests that should be carried out following the building or recalibration of a variable demand model, whereby the scale of response to given changes in cost is assessed. These tests are expected to demonstrate that the elasticity response is within a specified range where elasticity is defined as:

$e = (\log(T^1)-\log(T^0))/(\log(C^1)-\log(C^0))$,

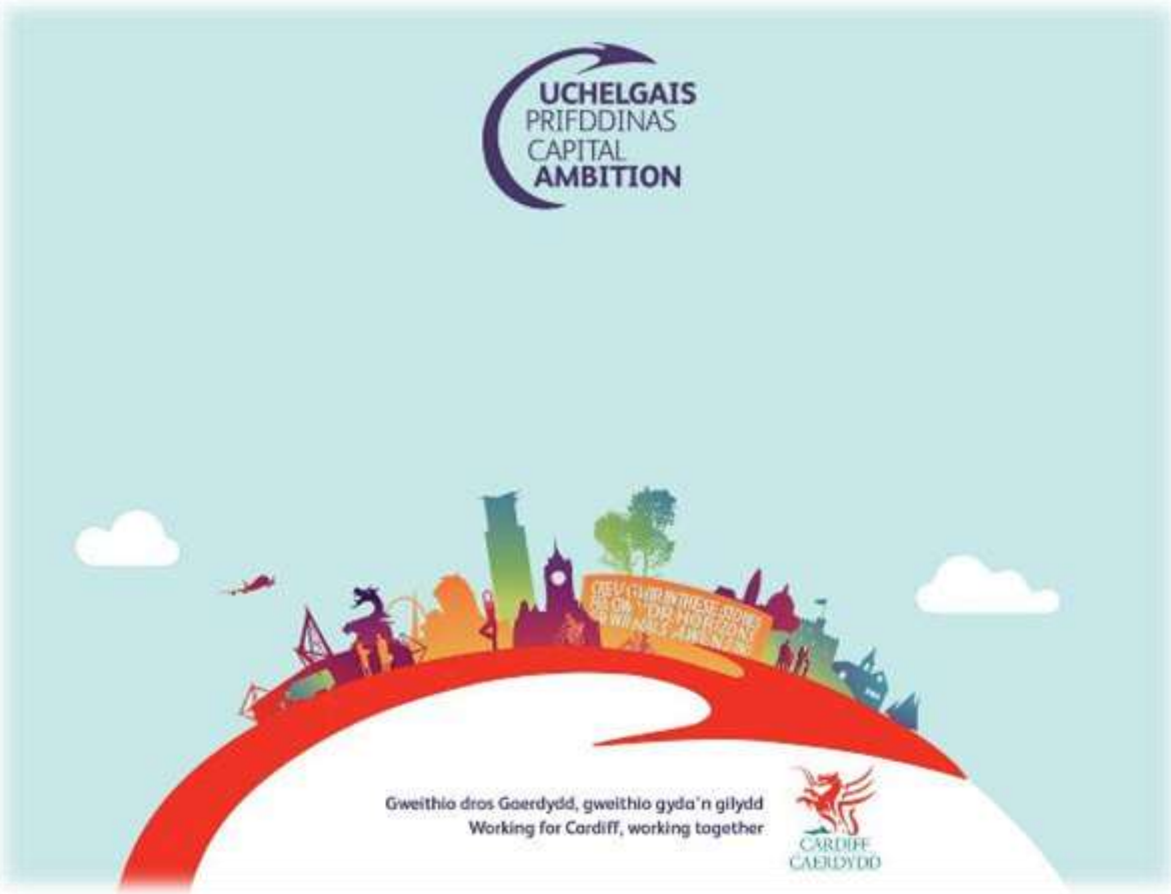
where the superscripts 0 and 1 indicate values of demand, T, and cost, C, before and after the change in cost, respectively.

The elasticity of the number of car trips with respect to a change in travel time is one of the tests specified, and has been carried out on SEWTM, yielding a model-wide elasticity value of -0.10 (demand weighted across travel purposes), which is in the recommended range defined in WebTAG.

For a given change in travel time, this elasticity value can be applied to estimate a change in the number of car trips for a given change in cost. It should be noted that this is a simple methodology for capturing a wide range of responses and is not generally recommended by WebTAG. In particular it cannot account for trips which change their destination (rather than cancelling or switching modes), and the model wide elasticity is not specific to trips around the scheme area. It is, however, sufficient to provide a simple understanding of the potential overestimate of the economic disbenefits.

This methodology would usually have to be iterated in a similar way to a variable demand model to produce an accurate estimation of demand change due to the scheme. However, only a single iteration has been implemented to indicate the broad range by which the disbenefits might change when run through a VDM. The overall economic disbenefits for the single year TUBA were reduced by 8.6% when tested using this method.

Clean Air Strategy & Action Plan for Cardiff



March 2019

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Chapter 1- The Need for a Clean Air Strategy & Action Plan

Clean air is essential for a good quality of life, and poor air quality is considered the largest environmental risk to public health in the UK.[1] It has been reported that air pollution problems persist in Wales and pose significant public health risks.[2] The evidence linking poor health outcomes with exposure, even low pollutant concentrations, only continues to strengthen. It is therefore plausible that everyone is affected by air pollution to some extent.[3] In the UK, in the context of air quality management, the main air pollutants which are the primary public health concern, are particulate matter, and nitrogen dioxide (NO_2), and the principle source of these pollutants is from road transport emissions.[4]

It has been published that air quality has significantly improved in the UK over the past years.[5] Defra states "Total UK emissions of nitrogen oxides (NOx) fell by almost 70% between 1970 and 2015 and by over 19% between 2010 and 2015." In Wales, the most widely exceeded limit value is the annual mean nitrogen dioxide concentration (40µg/m^3).

Despite these somewhat improved levels, there are around 40 Air Quality Management Areas (AQMAs) declared by Local Authorities in Wales. Very few AQMAs have been revoked and those persons living and working within these defined areas are susceptible to high concentrations of air pollutants than elsewhere. Welsh Government (WG) explain that from a public health perspective there is no defined 'safe' level of exposure, and the national air quality objectives used to identify AQMAs should not be seen as 'safe' levels. Air pollution can cause adverse effects on health and quality of life at lower exposures, depending on the circumstances of the exposed individual. As a consequence, the majority of the avoidable health burden associated with air pollution in Wales is the result of population exposures outside AQMAs.

High on the agenda for UK Government is to tackle air pollution and protect the health and well-being of the UK population.[5]

A multi-sectorial approach is needed to develop and effectively implement long term policies and strategies that reduce risks of air pollution to health (WHO Regional Office for Europe 2013). This approach is supported across Wales through the Well-being of Future Generations (Wales) Act 2015[6] (National Assembly for Wales 2015), that includes goals to achieve a healthier Wales, that is more globally responsible and equal, through thinking more about the long-term, looking to prevent problems and taking a more joined-up approach. Many of the actions required to address air quality will have additional benefits to health and well-being by increasing levels of physical activity, improving mental well-being, and decreasing social isolation.

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[1]World Health Organisation (2017). Evolution of WHO air quality guidelines: past, present and future.

[2] Welsh Air Quality Forum (2015). Air pollution in Wales 2015.
[3] Welsh Air Quality Forum (2016). Air pollution in Wales 2016.
[4] Brunt, H., Barnes, J., Jones, S., Longhurst, J., Scally, G. and Hayes, E. T. (2017) Air pollution, deprivation and health: Understanding relationships to add value to local air quality management policy and practice in Wales, UK. Journal of Public Health, 39 (3). pp. 485-497. ISSN 1741-3842.
[5] UK Government (2017). Air Quality plan for nitrogen dioxide (NO2) in the UK (2017).
[6] Welsh Government. Well-being of Future Generations (Wales) Act 2015.

CC is very aware of the concerns for air quality impacts. CC is committed to achieving levels as low as reasonably practicable by demonstrating levels beyond the annual objectives set for pollutants. In order to improve the air quality in Cardiff, action needs to be taken across the city as a whole and it is acknowledged that road traffic emissions (particulate matter (PM) and primary/ secondary nitrogen dioxide (NO_2)) are the primary contributing factor to poor air quality in Cardiff.

As outlined by Table 1- Composition of Cardiff's Vehicle Fleets Cardiff's licensed vehicle fleet contains a greater percentage of cars than the UK average, although a lower proportion of those are diesel powered.

Table 1- Composition of Cardiff's Vehicle Fleets

Area	Cars	% Diesel Cars	Light Goods Vehicles	% Diesel Vans	Heavy Goods Vehicles	Buses and Coaches
Cardiff	88.6%	36.5%	7.3%	96.4%	0.6%	0.5%
UK Average	82.8%	39.6%	10.1%	96.3%	1.3%	0.4%

WG'S publication; Local Air Quality Management, Policy Guidance, June 2017 recommended two clear goals:

(1) achieve compliance with the national air quality objectives in specific hotspots; and

(2) reduce exposure to pollution more widely, so as to achieve the greatest public health benefit.

Collective efforts, therefore, should look beyond targeted action in localised air pollution hotspots and do this in parallel with universal action to reduce risks for everyone.

Cardiff Council's (CC) Capital Ambition recognises that Cardiff is one of the UK's fastest growing cities, and that it is crucial that this growth is well planned and sustainable. One of the current administrations top priorities is implementing and sustaining a cohesive transport system, therefore addressing congestion and improving air quality in Cardiff. In line with the Capital Ambition report and WG's guidance, CC's Clean Air Strategy (CAS) & Action Plan will help implement and deliver the priorities set out in the Capital Ambition with an overarching aim to:

Improve Air Quality to Protect and Improve Public Health in Cardiff

As a major base of employment in South Wales, an improvement in air quality in Cardiff will not only benefit residents of the city but also those persons commuting from the wider region to the capital.

Actions to address the health impacts of air pollution in Cardiff can play a critical role in supporting other priorities such as active travel, health inequalities, integrated care, sustainability, growth and regeneration, localism and community engagement.

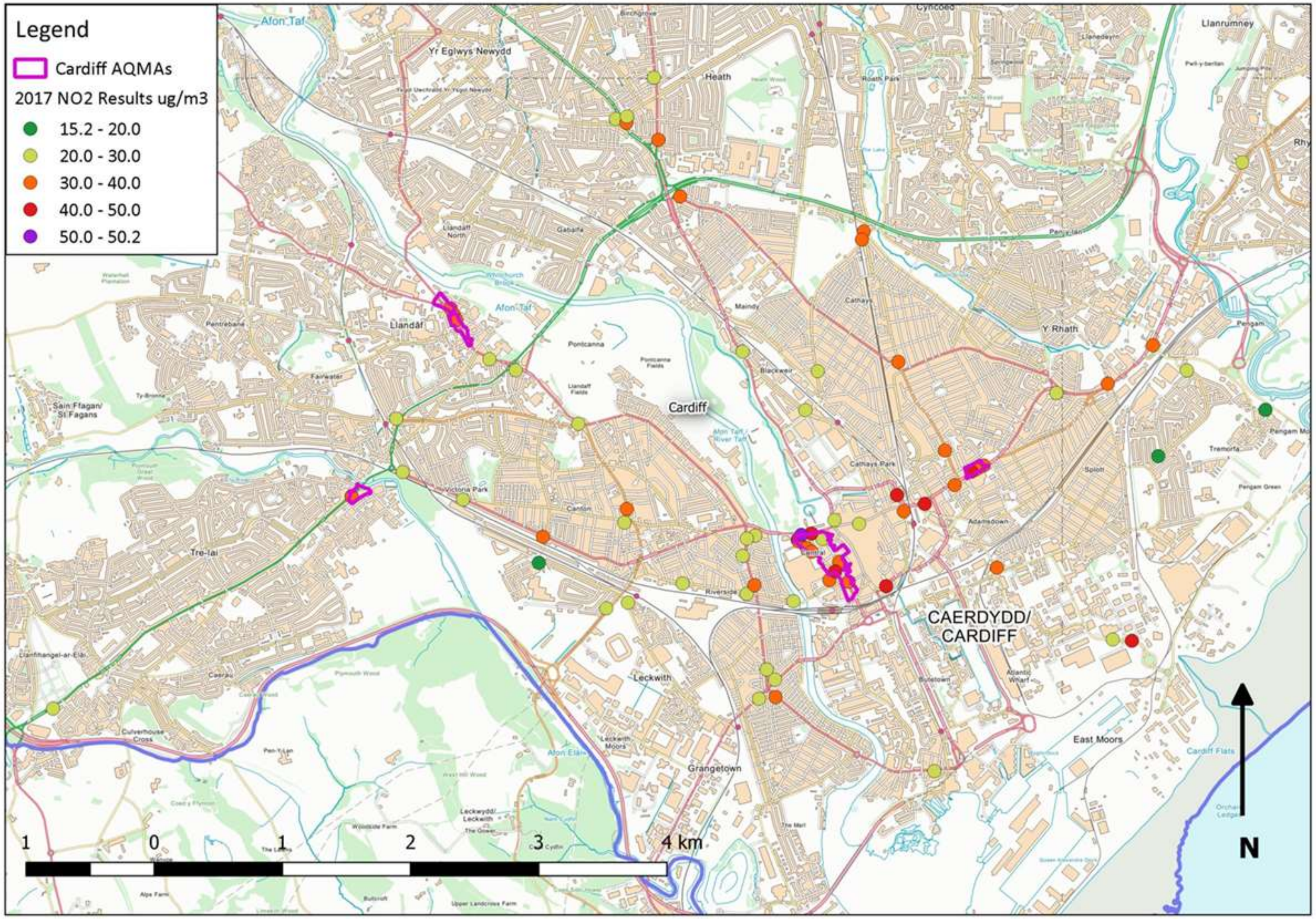
Based on monitoring results and further detailed assessments, there are currently four Air Quality Management Areas (AQMAs) declared across Cardiff which have all been declared due to exceedances of the annual mean NO_2 Air Quality Standard (40ug/m^3).

Two AQMAs are primarily focused in Cardiff City Centre: **Cardiff City Centre AQMA**, established 01/04/2013 and **Stephenson Court AQMA**, established 01/12/2010.

North of the City Centre, lies the **Llandaff AQMA** (established 01/04/2013) and to the west of Cardiff is the **Ely Bridge AQMA** (established 01/02/2007).

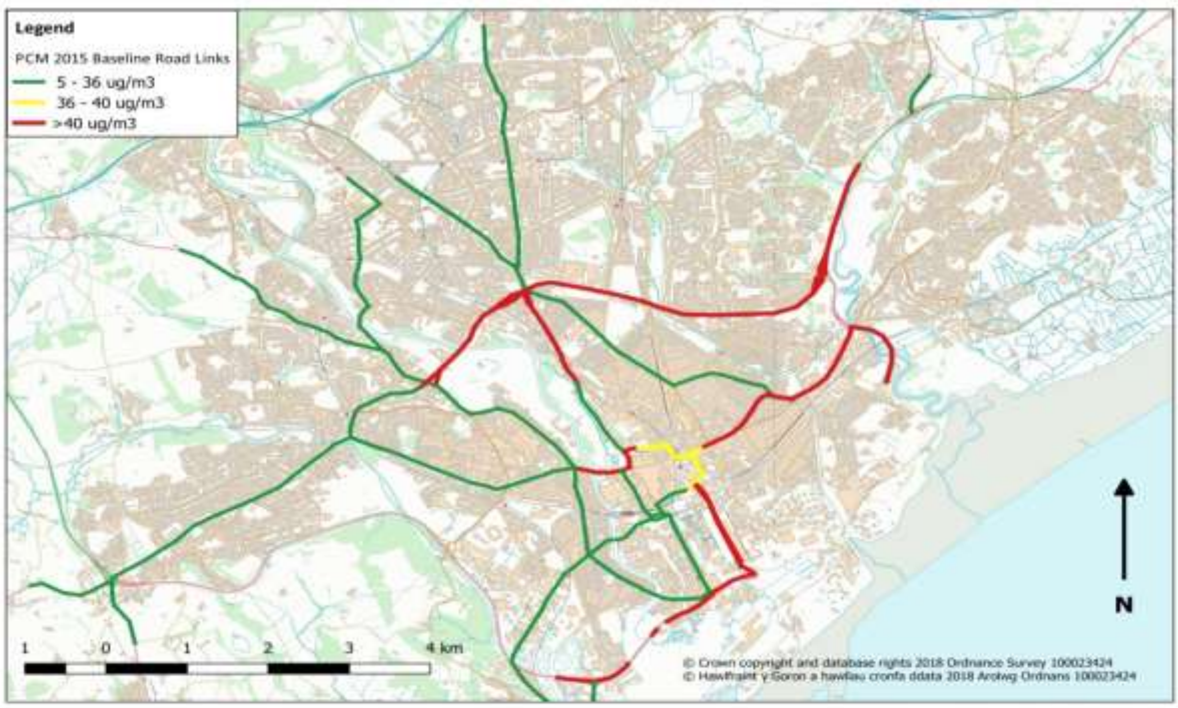
Figure 1- 2017 Monitored NO2 Results and Existing AQMAs in Cardiff displays the network of LAQM monitoring across Cardiff as well as highlighting the AQMAs.

Figure 1- 2017 Monitored NO2 Results and Existing AQMAs in Cardiff



Adding to the works undertaken by CC in accordance with its LAQM obligations, following the formal publication of Defra's UK detailed air quality plan to tackle roadside nitrogen dioxide (NO_2) concentrations in July 2017, it was identified from air quality monitoring undertaken by CC and modelled projections from WG that Cardiff would continue to exceed EU & UK Air Quality Directive Limit Values for NO_2 beyond 2020. Examining a baseline year of 2015 the report detailed modelled projections from JAQU which showed continued non-compliance of the national annual average NO_2 standard along identified road networks. The roads which have been modelled as exceeding the annual limit value are the A4161, the A4232, the A4234, the A470 and the A48. **Figure 2** displays the areas of concern;

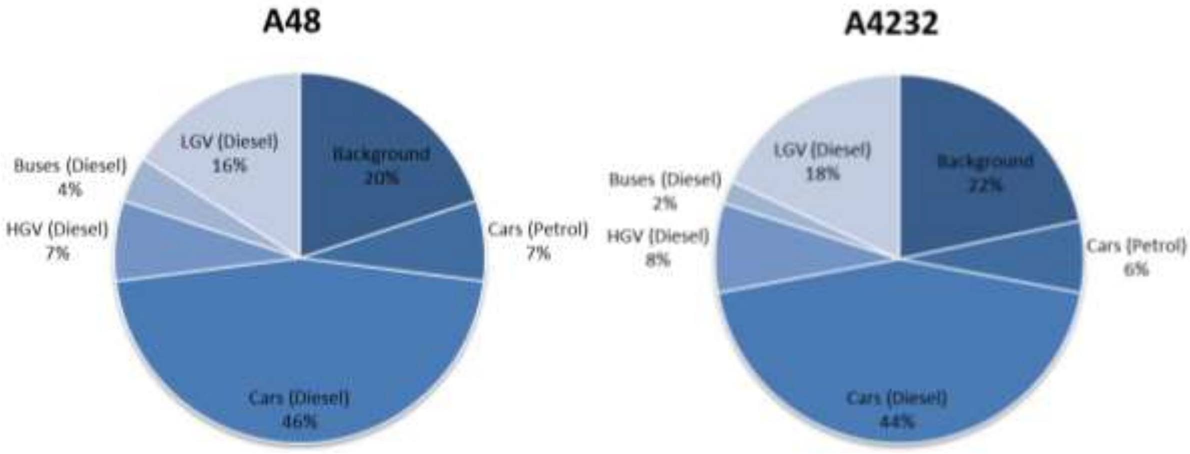
Figure 2- Updated Baseline NO_2 PCM Modelling Results Identifying Exceeding Road Links in Cardiff 2015



The particularly concerning road links are the A48 & A4232 whereby compliance for the annual average NO_2 is not achieved until beyond 2021.

Figure 3 represents the % NOx source apportionment for NOx pollution on the A48 and A4232 as modelled by the Department for Environment, Food and Rural Affairs (Defra)/Department for Transport's (DfT) Joint Air Quality Unit (JAQU). It is clear from this Figure that diesel cars account for the greatest source of pollution on this major road link in Cardiff.

Figure 3- NOx Emission % Source Apportionment, JAQU



As a result of the detail in the UK Plan, and a subsequent High Court ruling, in March 2018, under Part IV of the Environment Act 1995, Section 85(7), WG issued a formal direction to CC to address its air quality concerns, with particular reference to the specified five road links. The direction has been governed by the Welsh Minister for Environment who has determined that the direction deemed necessary to meet obligations placed upon the United Kingdom under the **EU Ambient Air Quality Directive (2008/50/EC).**

The Direction specifies that CC must undertake a feasibility study in accordance with the HM Treasury's Green Book approach[7], to identify the option which will deliver compliance with legal limits for nitrogen dioxide in the area for which the authority is responsible, **in the shortest possible time.**

This study will encapsulate the four AQMAs and strategic road networks in Cardiff, particularly the five highlighted pieces of road network.

The CAS & Action Plan appoints strategic measures that look to generate a positive impact to citywide air quality levels, in particular traffic derived NO_2 levels. Each measure has endured a cost benefit appraisal procedure by weighting the measures in terms of air quality impact, cost and timescale. The key theme of the strategic measures is to increase the uptake of sustainable modes of transport by influencing a behavioural change in Cardiff.

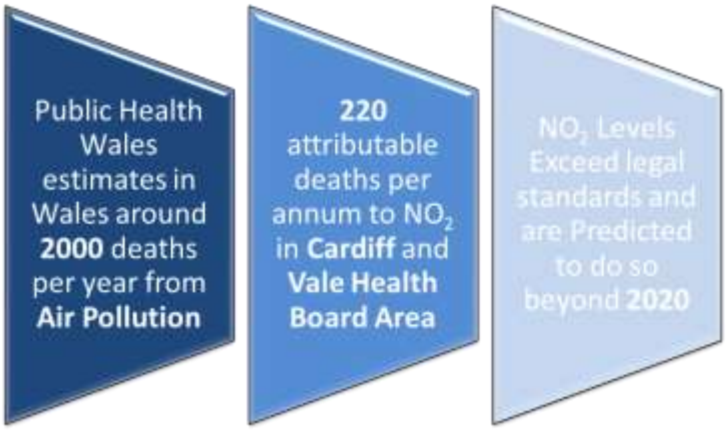
The strategic measures and assigned via the CAS & Action Plan forms the basis of the directed feasibility study, whereby results in terms of air quality impacts will be available once the Final Business Case for the feasibility study is complete.[8]

[7] HM Treasury Green Book
[8] Environment Act 1995 (Feasibility Study for Nitrogen Dioxide Compliance) Air Quality Direction 2018, 14th Feb 2018.

In order to achieve improvements in air quality and work towards fulfilling the main aim of this strategy, **strategic measures** need to be blanketed across the City via the successful implementation of defined actions. These strategic measures are listed below;

This document will outline various individual actions to implement these strategic measures in order to deliver significant improvements to air quality in Cardiff, whilst supporting the sustainable economic growth of the City and wider region. This will include a review of existing strategies, policies and plans which either have a direct or indirect impact on air quality in Cardiff.

Chapter 2- Background to Air Quality Issues



2.1 Public Health Impacts

There is clear scientific evidence which shows that air pollution exposure reduces life expectancy by increasing mortality and morbidity risk from heart disease, and strokes, respiratory diseases, lung cancer and other conditions[9]. Public Health Wales have stated that poor air quality is probably the second greatest health concern after smoking and is the most significant environmental determinant of health.

In the UK it has been estimated that an equivalent of **29,000** deaths are attributed to long term exposure to fine particulate air pollution exposure each year and an equivalent of **23,500** deaths are attributed to long term exposure to nitrogen dioxide (NO_2) exposure each year[10]. There is an overlap between the effects of both pollutants; as such, it has been estimated that the equivalent of **40,000 deaths** occur each year in the UK as a result of exposure to outdoor pollution[11]. On average, exposure reduces the life expectancy of every person in the UK by 7 to 8 months[12]. It has been estimated that reducing particulate air pollution by 10 µg/m3 in the UK would extend lifespan by five times more that eliminating casualties on the roads or three times more that eliminating passive smoking[13].

In Wales, based on data for the period 2011-2012, it has been estimated that an equivalent of **1,604** deaths can be attributed to fine particulate exposure each year, and **1,108** deaths can be attributed to nitrogen dioxide exposure each year[14]. Accounting for the pollutant effect overlap, it is estimated that an equivalent of around **2,000** deaths occur each year in Wales as a result of exposure to fine particulate and NO_2 exposure each year.

A study undertaken in 2014 published by Public Health England estimated that in **Cardiff 143** deaths were attributable to exposure to fine particulate air pollution.[15] More recent work by Public Health Wales estimates that there are 225 and 220 attributable deaths per annum to PM 2.5 and NO_2 in the Cardiff and Vale Health Board area[16]. As **Figure 4**

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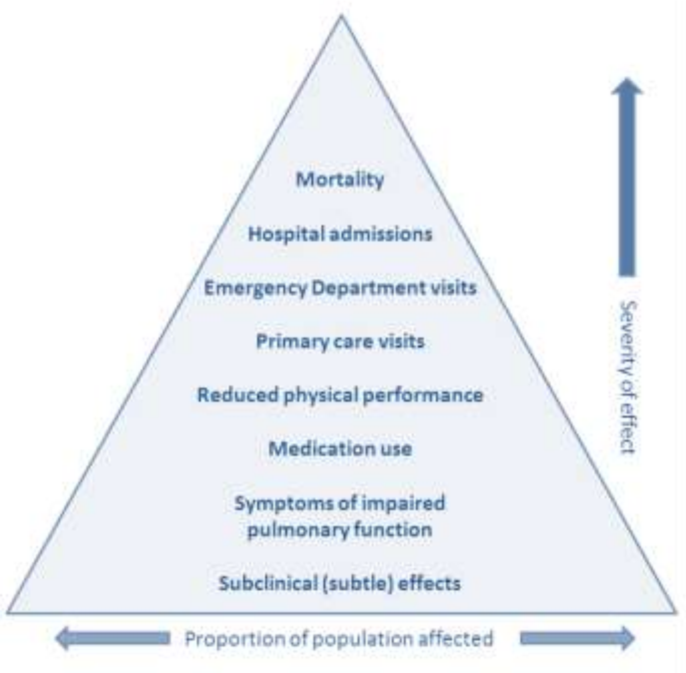
[9] WHO. Review of evidence on health aspects of air pollution-REVIHAAP. 2013. Copenhagen: WHO. From: http://www.euro.who.int/__data/assets/pdf_file/0004/193108/REVIHAAP-Final-technical-reportfinal- version.pdf ?ua=1
[10] Defra. Draft plans to improve air quality in the UK: tackling nitrogen dioxide in our towns and cities. UK overview document. 2015. London: Defra.
[11] Royal College of Physicians and Royal College of Paediatrics and Child Health (2016). Every breath we take: the lifelong impact of air pollution. From: https://www.rcplondon.ac.uk/projects/outputs/every-breath-we-take-lifelong-impact-airpollution
[12] Defra. The air quality strategy for England, Scotland, Wales and Northern Ireland (vol. 1). 2007.
[13] Defra (2017) Air Quality: Public Health Directors briefing. From https://laqm.defra.gov.uk/assets/63091defraairqualityguide9web.pdf
[14] Brunt., H (2017).
[15] Gowers., A. M, Miller., BG, Stedman., JR. Estimating local mortality burdens associated with particulate air pollution. 2014. London: Public Health England
[16] C&V deaths NO_2/ PM source needed

demonstrates, these figures are undoubtedly the tip of the iceberg when it comes to the health impact of air pollution. Taking action to improve air quality is therefore crucial in order to improve the health of the population in Cardiff.

Figure 4- Effects of Poor Air Quality in Terms of Population Affected and Severity



In 2012, the International Agency for Research on Cancer listed diesel exhaust pollution as a Class 1 carcinogen and extended this to all ambient air pollution in 2013.

For particulate air pollution and nitrogen dioxide there is no safe level of exposure and any initiatives to reduce air pollution will have positive health benefits. Welsh Government have indicated that the national air quality objectives used to identify Air Quality Management Areas (AQMAs) should not be seen as 'safe' levels and impacts are observed below levels permitted by current legal limits. Air pollution can cause adverse effects on health and quality of life at lower exposures, depending on the circumstances of the exposed individual. As a consequence, the majority of the avoidable health burden associated with air pollution in Wales is the result of population exposures outside AQMAs.

Although air pollution is a public health priority in Wales, its management needs to be a collaborative approach between public bodies, private companies, third sector partners and the public, all whom have important roles to play in addressing this pressing issue.

Poor air quality does not only have a significant health impact but it also has a wider societal cost. Accounting for health service costs and reduced productivity through lost work-days in the UK this is significant, standing at around £20b every year.[17]

Widespread air pollution is associated with routine car use for journeys within, into and out of, Cardiff. Well-designed measures to reduce air pollution will also increase active travel rates. Reducing reliance on the car as the primary mode of transport will have co-benefits of increased physical activity, mental well-being, and improved productivity and reduced stress, and will play a vital role in reducing carbon emissions which contribute to climate change.

[17] Royal College of Physicians and Royal College of Paediatrics and Child Health (2016). Every breath we take: the lifelong impact of air pollution.

The Director of Public Health's Annual Report 2017 highlights how our built environment has become increasingly shaped around car use over the last 50 years, with journeys made by car across the UK increasing from 27% to 83% over that period, while journeys made by bus have fallen from 42% to 5%, and by cycling from 11% to 1%. Over half of adults in our area are overweight or obese. To help reduce these levels, as well as levels of cardiovascular disease and type 2 diabetes, we need active travel to become the default for short journeys once again.

Nearly one in four vulnerable people in our communities report being lonely. A built environment shaped around cars can create community 'severance' where short journeys are difficult to make by foot or bicycle. This places vulnerable people (including older people and people with disabilities) who may not have access to car transport at a higher risk of social isolation and loneliness. Residential roads with high traffic volumes also report less neighbourliness and sense of community. Measures which reduce the impacts of cars on local communities may also have a positive impact on social interactions.

2.2 Air Quality Policy and Legislation

The Clean Air Strategy (CAS) and Action Plan looks to address air quality on a city wide basis and as such it considers both UK air quality objectives for LAQM purposes as well as EU limit values transcribed into UK legislation.

2.2.1 UK Air Quality Strategy and LAQM

The UK Air Quality Strategy[18] identifies nine ambient air pollutants that have the potential to cause harm to human health. These pollutants are associated with local air quality problems, with the exception of ozone, which is instead considered to be a regional problem.

The Air Quality (Wales) Regulations and subsequent amendments (National Assembly for Wales, 2000 and 2002) set objectives for the seven pollutants that are associated with local air quality. The objectives aim is to reduce the health impacts of those pollutants to negligible levels in Local Air Quality Management in Wales.

Welsh Ministers have a responsibility to ensure air quality levels in Wales comply with air quality limit values in accordance with the Air Quality Standards (Wales) Regulations, 2010.

Cardiff Council has a statutory duty under Part IV of the Environment Act 1995 & Air Quality Strategy for England, Scotland, Wales and Northern Ireland 2007 to manage local air quality. The Local Air Quality Management (LAQM) process places an obligation on all local authorities to regularly review and assess air quality in their areas, and to determine whether or not air quality objectives are likely to be achieved.

The air quality objectives applicable to LAQM in Wales are set out in the Air Quality (Wales) Regulations 2000, No. 1940 (Wales 138) and Air Quality (Amendment) (Wales) Regulations 2002, No 3182 (Wales 298). Where the air quality reviews indicate that the air quality objectives may not be met the local authority is required to designate an Air Quality Management Area (AQMA). Action must then be taken at a local level and outlined in a specific Air Quality Action Plan (AQAP) to ensure that air quality in the identified area improves.

[18] https://www.gov.uk/government/publications/the-air-quality-strategy-for-england-scotland-wales-and-northern-ireland-volume-1

2.2.2 European Air Quality Directives

Air Quality Framework Directive (96/62/EC) on ambient air quality assessment and management defines the policy framework for 12 air pollutants known to have a harmful effect on human health and the environment. The limit values for the specific pollutants are set through a series of Daughter Directives.

European Directive 2008/50/EC consolidates existing air quality legislation (apart from the 4th Daughter Directive) and provides a new regulatory framework for PM2.5.

The UK Air Quality Standards Regulations 2010 came into force on 11th June 2010, replacing the previous Air Quality Standards Regulations 2007, and consolidated and transposed into national legislation the requirements of the European Directives 2008/50/EC and 2004/107/EC – the fourth Daughter Directive.

2.2.3 Air Quality Objectives and Limit Values

The air quality objectives and limit values currently applicable to the UK can be split into two groups. UK air quality objectives set down in regulations for the purposes of local air quality management, which are targets, and EU Limit Values transcribed into UK legislation, which are mandatory.

A summary of the UK Air Quality Objective and EU Limit Values for NO_2 and particulate matter (PM_{10} and $PM_{2.5}$) is given in **Table 2**. Furthermore, the UK has a target to reduce average concentrations of $PM_{2.5}$ at urban background concentrations by 2ug/m^{3}before 2020.

Table 2- UK and EU Air Quality Objectives for NO_2, PM_{10} and $PM_{2.5}$

	Pollutant	Standard/ Concentration	Measured As	Date to be achieved and maintained thereafter
UK Air Quality Objectives	Nitrogen Dioxide (NO_2)	200ug/m3 not to be exceeded more than 18 times per annum	1 Hour Mean	31.12.2005
		40ug/m3	Annual Average	31.12.2005
	Particulate Matter (PM 10)	50ug/m3 not to be exceeded more than 35 times per annum	24 Hour Mean	31.12.2004
		40ug/m3	Annual Average	31.12.2004
	Particulate Matter (PM 2.5)	25ug/m3	Annual Average	2020
EU Limit Values	Nitrogen Dioxide (NO_2)	200ug/m3 not to be exceeded more than 18 times per annum	1 Hour Mean	01.01.2010
		40ug/m3	Annual Average	
	Particulate Matter (PM 10)	50ug/m3 not to be exceeded more than 35 times per annum	24 Hour Mean	01.01.2010
		40ug/m3	Annual Average	01.01.2010
	Particulate Matter (PM 2.5)	25ug/m3	Annual Average	2015

2.3 Air Quality in Cardiff

2.3.1 Monitoring

In line with the CC's statutory duties under Part IV of the Environment Act 1995, Shared Regulatory Services (SRS) undertakes regular air quality monitoring at specifically allocated locations across Cardiff using automated and non-automated principles for ambient air nitrogen dioxide (NO_2), particulate matter (PM_{10} & $PM_{2.5}$), sulphur dioxide (SO_2), carbon monoxide (CO) and ozone (O_3).

Under Section 82 of the Environment Act 1995 every local authority has an obligation to regularly review and assess air quality in their areas, and to determine whether or not air quality objectives are likely to be achieved.

Currently there are 72 specifically allocated monitoring locations across Cardiff where monitoring for annual nitrogen dioxide (NO_2) concentrations is undertaken with the use of passive diffusion tubes. In addition, two automated AURN monitoring stations located on Frederick Street in the City Centre and Newport Road, Roath provide continuous monitoring for nitrogen dioxide (NO_2), particulate matter (PM_{10} and $PM_{2.5}$), sulphur dioxide (SO_2), carbon monoxide (CO) and ozone (O_3).

With regards to prioritising ambient air quality sampling locations, the Council adopts a risk based approach to any allocation of monitoring sites, considering the requirements of The Department for Environment, Food and Rural Affairs' (Defra) Local Air Quality Management Technical Guidance 16, February 2018.[19] The designated monitoring locations are assigned based on relevant exposure and where the certain Air Quality Objective levels for a particular pollutant applies. TG(16) states that annual mean objectives should apply at "All locations where members of the public might be regularly exposed. Building facades of residential properties, schools, hospitals, car homes etc."

2.3.2 Air Quality Management Areas

Where the air quality reviews indicate that the air quality objectives are not being achieved, or are not likely to be achieved, Section 83 of the 1995 Act requires local authorities to designate an Air Quality Management Area ('AQMA').

Based on monitoring results and further detailed assessments, there are currently four Air Quality Management Areas (AQMAs) declared across Cardiff which have all been declared due to exceedances of the annual mean NO_2 Air Quality Standard (40ug/m^3), known to be derived from road transport.

Two AQMAs are primarily focused in Cardiff City Centre: Cardiff City Centre AQMA, established 01/04/2013 and Stephenson Court AQMA, established 01/12/2010.

North of the City Centre, lies the Llandaff AQMA (established 01/04/2013) and to the west of Cardiff is the Ely Bridge AQMA (established 01/02/2007). **Figure 5** details the location of the AQMAs and provides results of the latest 2016 monitoring results for NO_2 monitoring across Cardiff.

[19] Defra. Local Air Quality Management, Technical Guidance (TG16), February 2018.

2.3.3 Air Quality Action Plan

Section 84 of the Act ensures that action must then be taken at a local level which is outlined in a specific Air Quality Action Plan (AQAP) to ensure that air quality in the identified area improves. CC therefore has a statutory requirement to produce an Air Quality Action Plan (AQAP) for each identified AQMA within the local authority area. After declaring an AQMA the authority must prepare a **DRAFT** Air Quality Action Plan (AQAP) within 18 months setting out measures it intends to put in place to improve air quality to at least the air quality objectives, if not even better. The AQAP must be **formally** adopted prior to 24 months has elapsed. AQMA(s) are seen by local authorities as the focal points to channel resources into the most pressing areas of pollution as a priority.

In the case of Cardiff, implementing individual AQMA action plans has not proven to be sufficiently successful. The main issue with this particular approach is that the AQAP focuses on introducing local measures to individual road links/ areas, which only targets at improving air quality within the identified AQMA itself. Importantly, the absence of an AQMA in parts of Cardiff does not mean there is no public health problem from air pollution.

Whilst such measures have been successful in improving air quality within the individual AQMA (High Street/ St Mary's Street Action Plan) such localised measures can, and have led, to adverse impacts on air quality in surrounding areas and result in more widespread air quality issues. These plans have not looked sufficiently at the primary cause of the problem, this being road traffic derived emissions, resulting in air quality levels being detrimentally increased in neighbouring areas.

CC recognises action needs to be taken across the city as whole and it is acknowledged that road traffic emissions (particulate matter (PM) and primary/ secondary nitrogen dioxide (NO_2)) are the **primary** contributing factor to poor air quality in Cardiff. CC's Capital Ambition report recognises that Cardiff is one of the UK's fastest growing cities, and that it is crucial that this growth is well planned and sustainable. Reducing the number of car journeys made in the city, and promoting the use of active and sustainable modes of travel are central to Cardiff Council's Transport Strategy and in improving air quality in the

CC recognises that in order to tackle these known pockets of poor air quality, a more suitable and constructive approach is required to target the whole of Cardiff, improving overall air quality. With the implementation of correct long term measures, all highlighted road networks and identified AQMAs should be able to benefit from improved air quality. The recent Welsh Government guidance on local air quality management recommended two clear goals:

1. achieve compliance with the national air quality objectives in specific hotspots; and
2. reduce exposure to pollution more widely, so as to achieve the greatest public health benefit.

Collective efforts, therefore, should look beyond targeted action in localised air pollution hotspots and do this in parallel with universal action to reduce risks for everyone.

It has been highlighted that any formal AQAP need to be devised via the involvement and input of various influencing sectors across local authority bodies and partner agencies. CC has acknowledged this approach which will allow for increased awareness within the council and fundamentally will produce an effective action plan, supporting the desirable outcome of reaching lowest levels reasonably practicable, and maximising health benefits to the residents of Cardiff and commuters to the Capital.

It is important to note the recent report by National Institute for Health and Care Excellence (NICE) [20]suggests that small-scale actions on their own are unlikely to lead to the significant reductions in air pollution needed to protect health. Rather, it is recommended that multiple interventions are driven forwards in parallel; with each producing a small benefit, a multiple-intervention approach would likely act cumulatively to produce significant change (both in terms of air pollution mitigation and population health adaptation and improvement).

2.3.4 Local Air Quality Targets

CC recognise that there is no defined "safe level" when describing levels of air quality[21]. **CC is committed** to achieving NO_2 levels **as low as reasonably practicable** in the shortest time possible by demonstrating levels beyond the annual objective set for NO_2 (40µg/m^3).

In 2018, a corporate decision was made to implement a local performance indicator for annual average levels of nitrogen dioxide (NO_2) achieved within Cardiff Council's Air Quality Management Areas (AQMAs).

Annual mean ratified concentrations of nitrogen dioxide (NO_2) are not to exceed 35µg/m3. This objective applies to locations within Cardiff's Air Quality Management Areas (AQMAs) where members of the public might be regularly exposed, such as building façades of residential properties, schools, hospitals, care homes.

Datasets for annual average NO_2 levels recorded at relevant public exposure locations within the AQMAs do not display signs of improvement; levels are consistently elevated and are seen to be either exceeding or encroaching on the annual average NO_2 objective. **Table 3** draws upon worse case ratified NO_2 datasets monitored via passive diffusion tubes at most relevant sensitive receptor locations, i.e. residential facades within each AQMA.

Table 3- Five year dataset for monitored annual average NO_2 levels at residential facades.

AQMA	Site ID	Bias Adjusted Annual Average NO_2 Concentration (µg/m^3)				
		2013	**2014**	**2015**	**2016**	**2017**
City Centre	143	**42.1**	**42.1**	38.2	38.7	38.4
Stephenson Court	131	**43.9**	**41.2**	39.5	39.6	**41.7**
Ely Bridge	117	**44.9**	**42.3**	39.5	**41.3**	38.0
Llandaff	161	39.1	37.2	32.3	35.0	33.4

As displayed by **Table 3**, although it can be suggested that compliance is met for three of the four AQMAs, CC do not consider these levels **as low as reasonably practicable**. With Cardiff's expected future growth and approved development works already in

[20] NICE (2017). Air pollution: outdoor air quality and health. NICE Guideline NG70
[21] Local air quality management in Wales Policy guidance June 2017

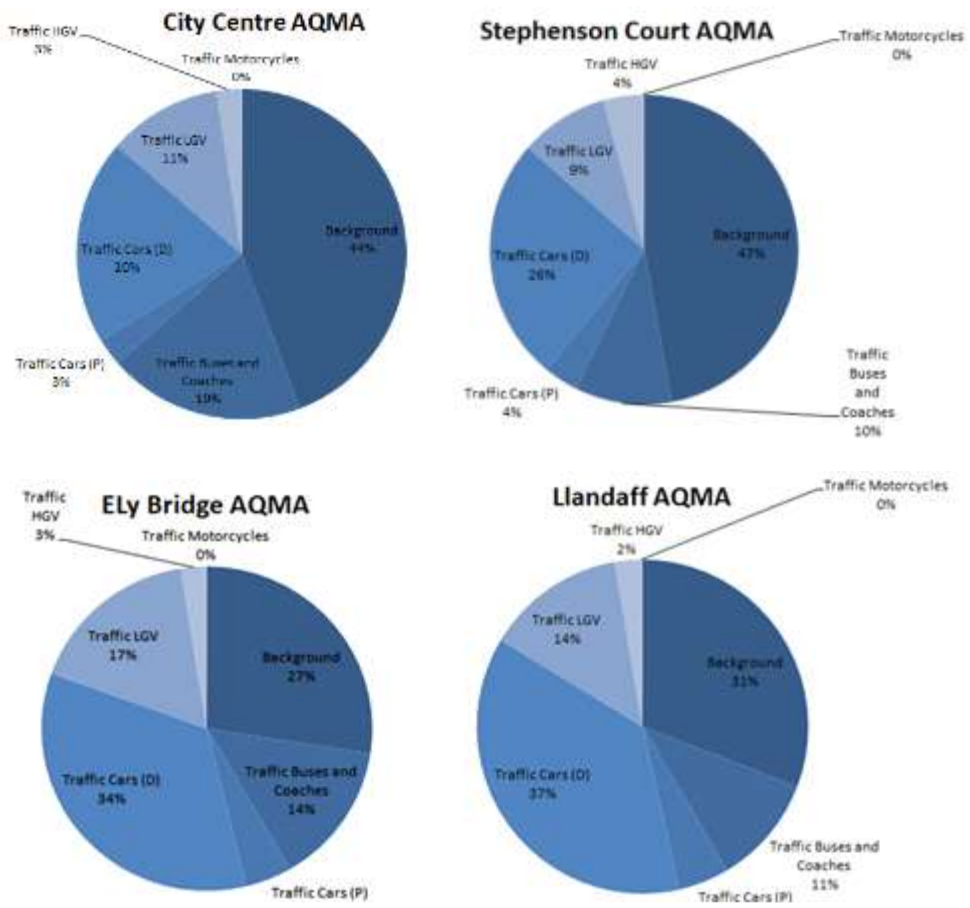
progress, further work is needed to ensure compliance with the air quality objectives is of a greater magnitude. Although CC does have a commitment to achieving NO_2 levels **as low as reasonably practicable**, targets must be set, therefore CC is committed to achieving annual average bias adjusted levels **<35µg/m3** at all monitored sensitive receptor locations (residential facades) within the AQMAs. It is suggested that the probability percentage of compliance exponentially decreases with annual average levels close to the 40µg/m3 annual mean objective. In order to ensure compliance is achieved at sensitive receptor locations within the established AQMAs, an annual average target level of 35µg/m3 is sought to be acceptable.

In order to monitor CC's identified strategic measures and their effectiveness, CC will continue to monitor levels of NO_2 at various relevant exposure locations citywide. CC will look at improving the network of monitoring across the city by examining ways of increasing monitoring capabilities, for example looking at personal air quality monitoring for the public and purchasing automatic monitoring equipment to provide a further understanding of air quality trends. CC will also design a transport monitoring programme which will look to examine different modes of transport trends, undertaken on a yearly basis. The scope for such a transport study would include examining figures for cycle trips, school journey mode determination, bus patronage, trends in peak traffic flow times and fleet composition analysis using routes through AQMAs and surrounding road networks.

2.3.5 Source Apportionment

Source apportionment analysis within Cardiff's AQMAs has been undertaken. Using available 2017 DfT data and adopting the guidance outlined in Local Air Quality Management (LAQM) Technical Guidance 16, Box 7.5, the percentage proportion of various vehicle classifications contributing towards measured annual average NO_2 concentrations was quantified. The analysis confirms that a large percentage proportion of NO_2 levels experienced at sensitive receptor locations within the established AQMAs is attributed by cars (predominantly diesel models), as well as buses & coaches. The analysis is detailed in Figure 5.

Figure 5– AQMA NO_2 Source Apportionment Assessments



2.3.6 Air Pollution and Areas of Deprivation

Different people are affected in different ways by air pollution and some people are more at risk than others. For example, children, older people and those with chronic lung or heart conditions are more vulnerable to the effects of air pollution. There are also others at a higher risk e.g. those working in polluted places or commuting to work through heavily congested urban areas. Air pollution can disproportionately affect vulnerable population groups (e.g. children, older people, people with underlying chronic disease), as well as those exposed to higher levels because of living or commuting in urban or deprived locations (National Institute for Health and Care Excellence 2017; WHO Regional Office for Europe 2016).

Research also shows that people living in the deprived areas may also be more susceptible to air pollution than those who live in the least deprived areas and may also be exposed to high air pollution concentrations. The triple jeopardy concept - where air pollution, impaired health and deprivation interactions can create disproportionate disease burdens between and within communities - is at play in Cardiff.

In 2015, the Royal College of Physicians and the Royal College of Paediatrics and Child Health published a report on the lifelong impact of air pollution and concluded that air pollution as a stressor that interacts with many other stressors such as diet, socio-economic deprivation and climatic conditions to create adverse health impacts and increased susceptibility to disease.

Exposure to air pollution and the consequent health risks and impacts are not uniform. Air pollution combines with other aspects of the social and physical environment to create an inequitable disease burden on more deprived parts of society (WHO Regional Office for Europe 2013).

Figure 6 below overlays the most recent NO_2 monitoring data onto the latest health deprivation map for Cardiff, as detailed in the Welsh Index of Multiple Deprivation (WIMD), produced by Welsh Government, 2014. From this Figure it is evident that Cardiff may not exactly follow the Wales wide data, as it is evident that in some of the most deprived areas air quality is relatively good. However this is based on limited monitoring locations in these areas, with no monitoring in some areas of high deprivation, and it therefore highlights that further air quality monitoring should be considered in the most vulnerable population areas, where any relevant exposure is likely to occur.

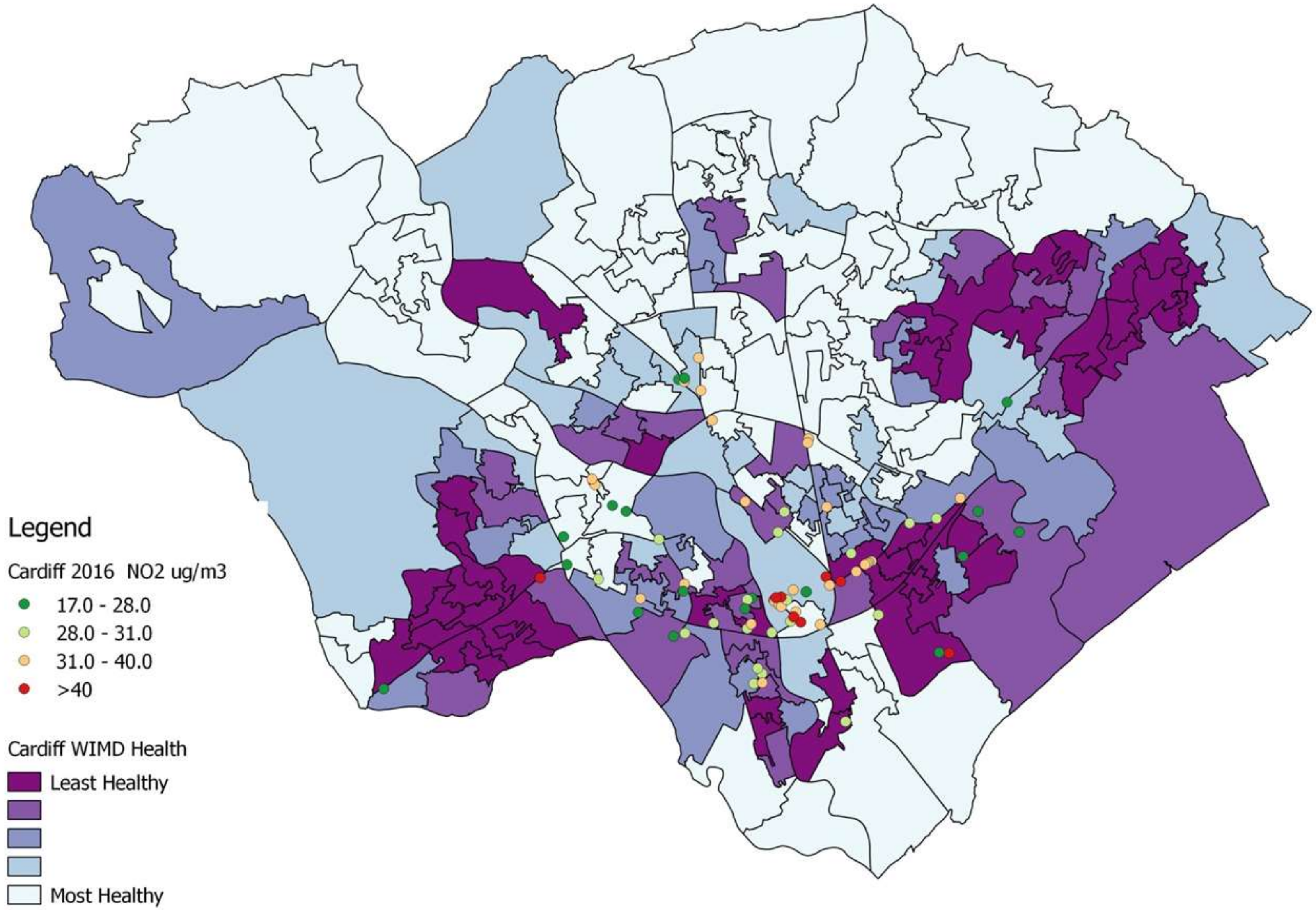
2.3.7 Clean Air Zones

As previously discussed in Chapter 1 the latest UK published document issued by Defra to mitigate road transport emissions illustrates projections for road links where, based on revised air dispersion modelling, NO_2 non-compliance will continue beyond 2020. The revised modelling has utilised revised emission factors and underpins areas in Wales whereby non-compliance for NO_2 is expected for 2020 and beyond, if no further action is implemented to improve air quality.

The published report outlined that the results of the modelling undertaken by Defra indicates that Cardiff may benefit from the introduction of a Clean Air Zone (CAZ), in order to achieve compliance with the national annual mean NO_2 objective in the shortest time possible. Defra's report stipulates that having a CAZ introduced in Cardiff by 2021 would ensure NO_2 compliance by 2022.

The road links predicted to exceed the national annual average NO_2 compliance value are shown in **Figure 2**.

Figure 6- Cardiff NO_2 Data 2016 and 2014 WIMD Health Data for Cardiff



As highlighted in Figure 2 the revised modelling undertaken on behalf of WG has projected continued non-compliance of the national annual average NO_2 standard by 2021 along the A48, Eastern Avenue and the A4232 near the Cardiff Bay Retail Park.

The Welsh and UK Governments have required all affected Local Authorities to detail and quantify all mitigation measures which would improve air quality and bring about compliance with national NO_2 objectives. The implementation of a Clean Air Zone (CAZ) is regarded as a "***last resort"*** approach after all other potential measures have been assessed. However, this strategy will consider the possibility of the introduction of a CAZ in Cardiff and this is detailed further in the Regulatory Measures section of this report Chapter 7.

2.4 Local Issues Impacting on Improving Air Quality

Research has shown that the car is the dominant mode of travel for journeys in Cardiff.[13] In order to improve air quality, which will play a vital role in contributing to health improvements in Cardiff, an increased use of sustainable and active travel alternatives is essential.

Cardiff Council is committed to achieving a 50:50 modal spilt by 2026, as set out in Cardiff's Local Development Plan (LDP) 2006- 2026[22]. However, there are a number of challenges that Cardiff faces in order to meet the 50:50 modal split;

- **Future Growth** - Cardiff's LDP provides for 41,000 new homes and 40,000 new jobs in Cardiff by 2026. It is envisaged that this level of growth will generate a (net) road traffic increase by 32% and so existing pressures on Cardiff's transport network will be intensified. A significant shift is required from car use to sustainable travel;

- **Inbound Commuting Traffic** - 38% of Cardiff's workforce travel to Cardiff from outside the county area. This commuting workforce from outside the county area has seen a 10% increase 2004 - 2014. Figures from the Census conducted in 2011 suggest that between 76% - 84% of the commuting workforce travel by car;

- **Health -** There is an urgent need to encourage healthy and active lifestyles in Cardiff; only 25% of Cardiff residents meet physical activity guidelines and 53% are obese or overweight (Welsh Health Survey 2010 and 2011). Social isolation and loneliness is another major need in our local population;

- **Sustainable and Active Travel Availability** - Areas poorly served by sustainable transport modes often have high levels of car ownership and become heavily reliant on the car for daily travel. The quality of the public transport network is major challenge for Cardiff; Ask Cardiff Surveys outlined a 4% decrease in daily bus use between 2007 and 2014. Across the UK over the last 5 years the cost of running a car has decreased by 5% while the cost of the bus has increased by 14% (Department for Transport). There is also a need for cycling and walking improvements in Cardiff. Levels of cycling are continuing to increase but 82% of Cardiff residents think cycling safety needs to be improved (Bike Life 2015).

[22] Cardiff Council Adopted Local Development Plan 2006-2026

Chapter 3 Planning and Development Control

Our built environment can affect the emission of road traffic related air pollutants by influencing how and how much, we travel. It can also affect the way air pollutants are dispersed through street design and the resulting impact on air flow (NICE 2017).

3.1 Prosperity for All

In September 2017, the Welsh Government published a national strategy, Prosperity for All[23] to deliver its key priorities during the latest term of the Assembly. One of the key themes of this strategy is to build healthier communities and better environments, and a key aspect of this theme is to reduce emissions in order to deliver improvements to air quality.

3.2 Well-being of Future Generations (Wales) Act 2015

In 2015 Welsh Government made a new law called the Well-being of Future Generations (Wales) Act. The new law has the sustainable development principle at its heart. This means that we need to work in a way that improves wellbeing for people today without doing anything that could make things worse for future generations.

The Well-being of Future Generations (Wales) Act 2015 (WFG) is a significant enabler to improve air quality as the Act calls for sustainable cross-sector action based on the principles of long-term, prevention-focused integration, collaboration and involvement. It intends to improve economic, social, environmental and cultural well-being in Wales to ensure the needs of the present are met without compromising the ability of future generations to meet their own needs. The Act places responsibilities on public bodies in Wales to work in new ways (including via Public Services Boards) towards national Well-being goals. Progress is measured against a suite of well-being and Public Health Outcomes Framework indicators; there is one specifically concerned with air pollution.

As Error! Reference source not found. illustrates below, the Act is the legislative vehicle for " Health in all Policies in Wales" and provides the underpinning principles for all policy and decision making, including economic development, in Wales. Reducing air pollution, health risks and inequalities can help contribute to most, if not all, of the well-being goals. As such,

[23] Welsh Government, 2017 – Prosperity for All

the Act presents excellent opportunities to change policy and practice to enhance air quality management arrangements across Cardiff (and wider).

The CAS & Action Plan ensures that future decision making in terms of air quality will comply with the WFG in terms of ensuring that the Council meets the five ways of working

•**Long term** – The CAS & Action Plan balances short-term needs of achieving compliance with the limits values in the shortest time possible, with the need to safeguard the ability to ensure longer term continued improvement in air quality within Cardiff.

•**Prevention** –By developing strategic measures, the Council should ensure improvements in air quality are achieved and will be able to prevent air quality getting worse in the future thus protecting public health and the wider environment.

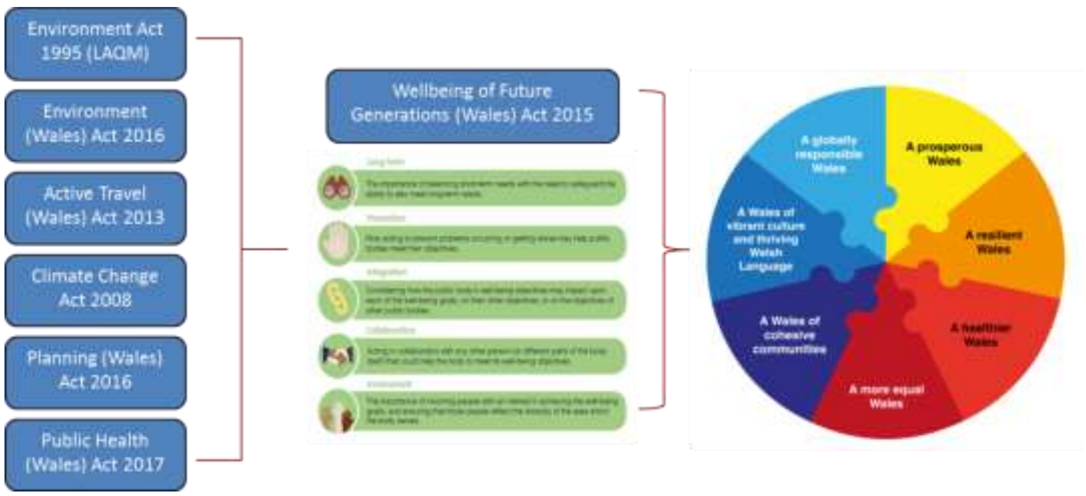
•**Integration** – The development of strategic measures takes into consideration other public body's well-being objectives and qualitatively assesses the impact upon each of the well-being goals, or the objectives of other public bodies.

•**Collaboration –**The development of the strategic measures has been done so in collaboration with many departments within the Council and other external organisations, i.e., Public Health Wales. This collaborative approach will be taken forward in the development of the initial plan as part of the feasibility study.

•**Involvement** – The prior to developing the Final Plan the preferred measures will be subject to an appropriate level of consultation, and will ensure that those who have a strong interest in improving air quality will be fully involved and their ideas considered.

Overall, improving air quality and developing a preferred option to achieve compliance with the NO_2 limit value, contributes significantly to the majority of the well-being goals.

Figure 7- The Well- being of Future Generations (Wales) Act 2015 Matrix



3.2.1 Cardiff Well-Being Plan 2018-2023

This CAS & Action Plan also supports the Councils Well-being Objectives, identified within the Council's Well Being Plan 2018-2023.

Under the Act the Cardiff Public Services Board (PSB) has produced its Well-Being Plan for 2018-2023[24], which sets out the Cardiff PSB's priorities for action over the next 5 years, and beyond. The Plan contains Well-being Objectives, high-level priorities that the Cardiff PSB have identified as being most important. It also contains 'Commitments,' or practical steps that the city's public services, together, will deliver over the next 5 years. The Well-Being Plan has set out Well-Being Objectives as follows:

- **Objective 1** - A Capital City that Works for Wales;
- **Objective 2** - Cardiff grows in a resilient way;
- **Objective 3 -**Safe, Confident and Empowered Communities
- **Objective 4** - Cardiff is a great place to grow up;
- **Objective 5** - Supporting People out of poverty;
- **Objective 6** - Cardiff is a great place to grow older; and
- **Objective 7 -**Modernising and Integrating Our Public Services

Within the Well-Being Plan Objective 2 details the following; *Cardiff is one of Britain's fastest growing cities, and is by far the fastest growing local authority area in Wales. Successful cities are those in which people want to live and this growth is welcomed and a sure sign of strength for the city. However, this growth will bring challenges too, putting pressure on both the city's physical infrastructures, community cohesion, its natural environment and public services. Managing the impacts of this population growth and of climate change in a resilient and sustainable fashion will be a major long term challenge for Cardiff.*

Improving levels of NO_2 and particulate matter ($PM_{10,\ 2.5}$) is a City level outcome indicator that the PSB will seek to impact in order to meet this specific Objective. The Plan forecasts a future Cardiff with improved air quality and has committed to taking '*a city-wide response to air pollution through supporting the development and delivery of a Cardiff Clean Air Strategy.'*

3.3 Planning Policy Wales

Land-use planning policy in Wales is established within the policy document Planning Policy Wales (PPW), Edition 10 (Welsh Government, 2018)[25] and its updates which provide the strategic policy framework for the effective preparation of local planning authority development plans. PPW is supported by a series of Technical Advice Notes (TANs) and National Assembly for Wales Circulars. Local planning authorities have to take PPW, TANs and Circulars into account when preparing Development Plans.

With respect to planning policy guidance, TAN 18 on transport (Welsh Government, 2007) makes reference to local air quality and the need for Air Quality Action Plans to be prepared for any Air Quality Management Areas declared.

PPW places a general presumption in favour of sustainable development, stressing the importance of local development plans, and states that the planning system should perform

[24] Cardiff Well-Being Plan 2018-2023
[25] Planning Policy Wales – 10th Edition December 2018

an environmental role to minimise pollution. Local development plans should enable consideration of the effects that the proposed development may have on air quality, as well as the effect that air quality may have on the proposed development. To prevent unacceptable risks from air pollution, planning decisions should ensure that new development is appropriate for its location.

The need for compliance with any statutory air quality limit values and objectives is stressed, and the presence of AQMAs must be accounted for in terms of the cumulative impacts on air quality from individual sites in local areas. New developments in AQMAs should be consistent with local air quality action plans.

Within the PPW document Welsh Government is committed to reducing reliance on the private car and supporting a modal shift to walking, cycling and public transport. Delivering this objective will make an important contribution to decarbonisation, ***improving air quality***, increasing physical activity, improving the health of the nation and realising the goals of the Well-being of Future Generations Act.

PPW outlines barely compliant levels of air quality should not be viewed as 'clean' and still carries long-term population health risks, and thus it is desirable to keep levels of pollution **as low as possible.**

3.4 Cardiff's Local Development Plan 2006-2026

Cardiff's Local Development Plan (LDP) 2006-2026, forms the basis for decisions on land use planning in Cardiff up to 2026 and assumes that, within the plan's time frame, approximately 40,000 new jobs and 41,100 new dwellings will be developed in Cardiff as a direct response to Cardiff's role as the economic driver of the City-region.

In addition to its independent examination, the LDP was subject to a Strategic Environmental Assessment (SEA) to ensure that the policies reflect sustainability principles and take into account environmental impacts.

Policy KP2 of the LDP allocates 8 Strategic Sites to help meet the need for new dwellings and jobs. These strategic allocations on both greenfield and brownfield sites will include 500 homes or more and/or include significant employment/mixed uses which will bring significant benefits to the city. The sites are:

- (i) Cardiff Central Enterprise Zone;
- (ii) Former Gas Works, Ferry Road;
- (iii) North West Cardiff;
- (iv) North of Junction 33 on the M4;
- (v) South of Creigiau;
- (vi) North East Cardiff (West of Pontprennau);
- (vii) East of Pontprennau Link Road; and
- (viii) South of St. Mellons Business Park – Employment Only.

The LDP identifies that sustainable transportation solutions are required in order to respond to the challenges associated with new development by setting out an approach aimed at minimising car travel, maximising access by sustainable transportation and improving connectivity between Cardiff and the wider region.

The Plan sets out a strategy to achieve this by making the best use of the current network, managing demand and reducing it where possible by widening travel choices. The aim is to secure a modal split of 50% car and 50% non-car modes.

The following LDP policies are of relevance to air quality;

KP8: SUSTAINABLE TRANSPORT
Development in Cardiff will be integrated with transport infrastructure and services in order to:

- Achieve the target of a 50:50 modal split between journeys by car and journeys by walking, cycling and public transport;
- Reduce travel demand and dependence on the car;
- Enable and maximise use of sustainable and active modes of transport;
- Integrate travel modes;
- Provide for people with particular access and mobility requirements;
- Improve safety for all travellers;
- Maintain and improve the efficiency and reliability of the transport network;
- Support the movement of freight by rail or water; and
- Manage freight movements by road and minimise their impacts

For Cardiff to accommodate the planned levels of growth, existing and future residents will need to be far less reliant on the private car. Therefore, ensuring that more everyday journeys are undertaken by sustainable modes of transport, walking, cycling and public transport, will be essential.

KP14: HEALTHY LIVING
Cardiff will be made a healthier place to live by seeking to reduce health inequalities through encouraging healthy lifestyles, addressing the social determinants of health and providing accessible health care facilities. This will be achieved by supporting developments which provide for active travel, accessible and useable green spaces, including allotments.

KP18: NATURAL RESOURCES:
In the interests of the long-term sustainable development of Cardiff, development proposals must take full account of the need to minimise impacts on the city's natural resources and minimise pollution, in particular the following elements......minimising air pollution from industrial, domestic and road transportation sources and managing air quality.

EN13: AIR, NOISE, LIGHT POLLUTION AND LAND CONTAMINATION
Development will not be permitted where it would cause or result in unacceptable harm to health, local amenity, the character and quality of the countryside, or interests of nature conservation, landscape or built heritage importance because of air, noise, light pollution or the presence of unacceptable levels of land contamination.

C6: HEALTH
Priority in new developments will be given to reducing health inequalities and encouraging healthy lifestyles through:

i. Identifying sites for new health facilities, reflecting the spatial distribution of need, ensuring they are accessible and have the potential to be shared by different service providers; and

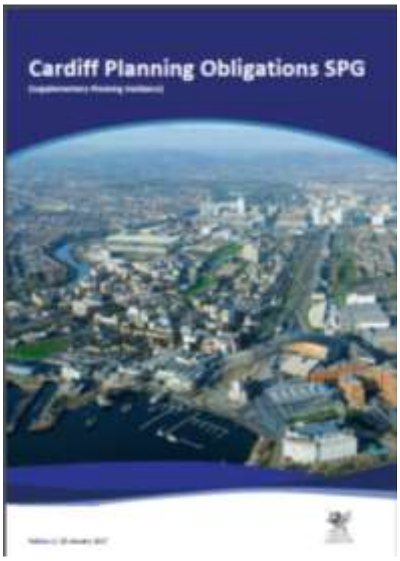
ii. *Ensuring that they provide a physical and built environment that supports interconnectivity, active travel choices, promotes healthy lifestyles and enhances road safety.*

The LDP also outlines the approach the Council will take to increase the proportion of people travelling by sustainable modes and to achieve the 50:50 modal split target. This will involve:

- enabling people to access employment, essential services and community facilities by walking and cycling through, for example, high quality, sustainable design and measures to minimise vehicle speed and give priority to pedestrians and cyclists;
- developing strategic bus and rapid transit corridor enhancements and facilitating their integration with the wider transport network;
- facilitating the transfer between transport modes by, for example, improving existing interchanges and developing new facilities such as strategically located park and ride facilities; and
- maximising provision for sustainable travel within new developments and securing infrastructure investment which can support modal shift within existing settlements.

3.5 Supplementary Planning Guidance (SPG)

In addition to the measures identified directly in the LDP the Council has recently prepared Supplementary Planning Guidance (SPG) which supports and provides additional guidance on the policy aims of the LDP which will have benefits on Air Quality in Cardiff.



3.5.1 Planning Obligations SPG (January 2017)

This document sets out the Council's approach to planning obligations when considering applications for development. It provides further guidance on how the policies set out in the LDP are to be implemented and will assist in securing the provision of sustainable development across the city.

Poor air quality can impact on people's health / quality of life and local authorities are required to assess air quality in their areas against National Air Quality Standards. Where the need arises as a result of a proposed development, the document confirms that developers will be requested to provide an Air Quality Assessment (AQA) and, in the event of an adverse assessment, a proposed scheme of mitigation measures. In addition to a scheme of mitigation measures, a financial contribution may be sought towards the site specific monitoring of air quality emissions.

In respect of Transportation and Highways, the SPG confirms the Council will maximise opportunities for trips generated by new development to be made by walking, cycling and public transport and seek to ensure that the highway network is able to accommodate road traffic movements associated with new development in a safe and efficient manner. The following guidance is covered:

(i) developments requiring the provision of a Transport Statement or Transport Assessment;

(ii) the provision of on-site infrastructure necessary to serve the development;

(iii) the provision of or contribution towards offsite highway works, public transport infrastructure/facilities provision and local interventions where the need arises;

(iv) integrating public transport; and

(v) travel plans detailing a long term management and monitoring strategy for the delivery of sustainable transport objectives through positive action.

3.5.2 Managing Transportation Impacts (Incorporating Parking Standards) SPG

This SPG sets out Cardiff Council's approach to assessing and managing the transport impacts of developments and supplements the transport and other related policies in Cardiff's Local Development Plan 2006-2026. It applies to all categories of development for which planning permission is required, including new developments, extensions, redevelopments and material changes of use.

The SPG provides detailed guidance with regard to:

1) How the Council will consider the impacts of development on the routes that make up the local highway network.
2) The detailed information that applicants for planning permission should include with their submissions to enable the Council to make a fully informed assessment of transport impacts.
3) The Council's approach to quantifying and assessing the transport impacts of development proposals as part of its determination of planning applications.
4) The types of transport infrastructure and other mitigation measures which may be sought to address transport impacts.
5) How the Council will seek to secure the transport infrastructure and other transport measures required to mitigate transport impacts, enable development to proceed and support the implementation of Transport policies in the Local Development Plan.
6) The scope and content of Travel Plans required as part of the overall package of measures to mitigate impacts and support the implementation of LDP transport policies.
7) The parking standards which apply to different types of development in specific areas of the city.
8) How the impacts of developments upon Public Rights of Way will be considered and the likely requirements for mitigation.

3.5.3 Cardiff Green Infrastructure SPG

Outlined in Cardiff's Local Development Plan (LDP) 2006- 2021, Policy **KP16** focuses upon Green infrastructure.

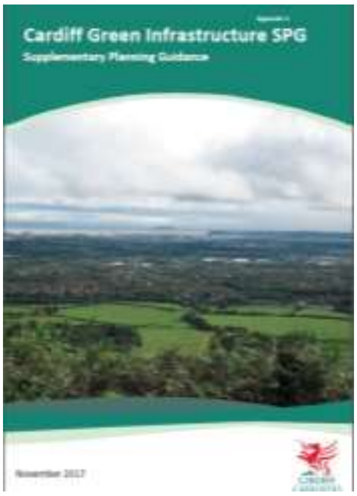
Green Infrastructure

The policy aims to ensure that Cardiff's green infrastructure assets are strategically planned and delivered through a green infrastructure network. Other policies in the Plan provide more detailed guidance on aspects of these assets, together with supporting SPG.

Where development is permitted, planning conditions and/or obligations will be used to protect or enhance the natural heritage network.

New developments should incorporate new and / or enhanced green infrastructure of an appropriate size, type and standard to ensure no fragmentation or loss of connectivity.

Where the benefits of development outweigh the conservation interest, mitigation and/or compensation measures will be required to offset adverse effects and appropriate planning obligations sought. The implementation of policies designed to provide and protect public open space throughout Cardiff would also serve to offset any increase in recreational pressure on the Cardiff Beech Woods SAC, thereby helping to avoid likely significant effect upon that site.



Management of Cardiff's green infrastructure network should be in place prior to development, and appropriate planning obligations sought. SPG on this topic will more fully outline the extent of Cardiff's green infrastructure and how this policy can be implemented in more detail.

A new Supplementary Planning Guidance (SPG) concerning Green Infrastructure was approved in 2017 by CC to provide a detailed understanding to the elements raised in the LDP.

- This document provides planning advice on a number of areas relating to development and the environment, including protection and provision of open space, ecology and biodiversity, trees, soils, public rights of way, and river corridors.

- The new document also differs from previous SPGs by providing more in depth design advice, aimed at giving developers a clearer understanding of the approach expected when submitting designs for new developments. By having this information up-front developers are better able to provide suitable designs to the Council through the planning process

The document sets out Cardiff Council's approach to the consideration of green infrastructure in relation to new developments, and will assist in securing the provision of sustainable development across the City as part of the Capital Ambition agenda.

The guidance will be used to ensure that all new developments satisfy the requirements for green infrastructure plan as set out in Policy KP16 of the LDP: *"Cardiff's distinctive natural heritage provides a network of green infrastructure which will be protected, enhanced and managed to ensure the integrity and connectivity of this multi-functional green resource is maintained.*

Protection and conservation of natural heritage network needs to be reconciled with the benefits of development. Proposed development should therefore demonstrate how green infrastructure has been considered and integrated into the proposals. If development results in overall loss of green infrastructure, appropriate compensation will be required."

3.5.4 Planning for Health and Well-being SPG

This document sets out the Council's approach to ensuring planning decisions consider impacts on the health and well-being of the population. The SPG is supplementary to Policies KP14 and C6 of the adopted LDP

Specifically in relation to air quality the SPG states that *"Air, noise and light pollution impacts on health and well-being, increasing the burden of disease from stroke, heart disease, lung cancer, and both chronic and acute respiratory diseases, including asthma. Invariably there is a disproportionate impact on disadvantaged groups. The importance of the need to consider this issue is set out in NICE (National Health and Care Excellence) Guidance 'Air pollution: outdoor air quality and health' which was published in June 2017."*

3.5.5 Planning Guidance for the Provision of Electric Vehicle Charging Points

In November 2018, the Council published a guidance documents for developers on the provision of charging points in new developments. This document sets out the Councils expectations on the minimum number of electric charging points that should be provided depending on the nature of the development. The expectations are summarised in Table 4 as follows:

Table 4 - Council Expectations on the Provision of EV Charging Points

Development Type	Provision
Houses	**One electric vehicle dedicated charging point** (up to 7kW(32A) where possible) **or installation of passive wiring** to allow future charging point connection per house with garage or driveway.
Flats	**At least 10% of parking bays** should be provide with dedicated electric vehicle weatherproof charging points.
Commercial Development, Car Parks and Community Facilities	**At least 10% of parking bays** should be provided with dedicated electric vehicle weatherproof charging points.
Public Transport Facilities and Taxi Ranks	Charging infrastructure will be required to facilitate the conversion of bus and taxi fleet, using **appropriate technological solutions at suitable locations across the city.**
Future Proofing	Subject to agreement with the Local Planning Authority standard provision may also require **installation of groundwork/passive wiring at the outset** to enable further future installation to match demand.

3.6 Development Management Consultations

The Local Planning Authority consults with the Shared Regulatory Services Air Quality Team on development proposals where air quality is a material consideration. A confidential pre-application enquiry process is available for developers to seek advice, obtain clarification and address any potential issues prior to the submission of a formal planning application. This confidential advice is given on a 'without prejudice' basis and precedes the statutory consultations which would be carried out during the planning application process.

3.6.1 Planning Conditions and Planning Obligations

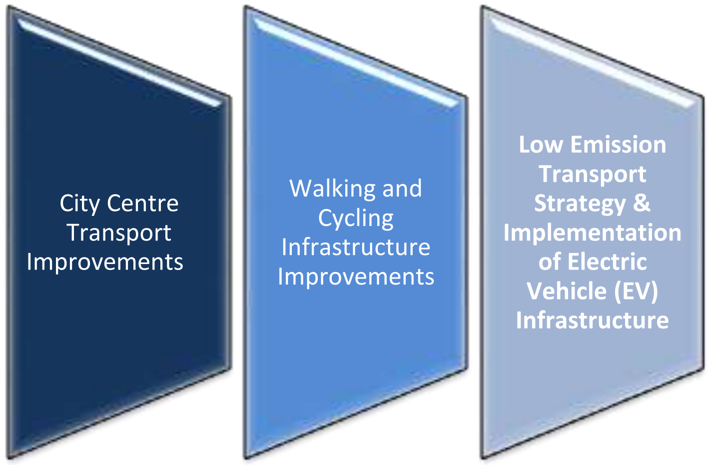
Many planning permissions are granted subject to various planning conditions. Conditions can enable many development proposals to proceed where it would otherwise be necessary to refuse planning permission. The proper use of conditions can improve the quality of development and enhance public confidence in the outputs of the planning system. Conditions should only be imposed where they are both necessary and reasonable, as well as enforceable, precise and relevant both to planning and to the development to be permitted.

Planning obligations are useful arrangements to overcome obstacles which may otherwise prevent planning permission from being granted. Contributions from developers may be used to offset negative consequences of development, to help meet local needs or to secure benefits which will make development more sustainable.

Planning obligations seeking to improve air quality may include contributions to enable the Council to improve monitoring capabilities.

The Council will look to draft a further SPG to provide specific guidance for addressing air quality impacts from new developments. The SPG will look to clearly set out the circumstances when an assessment for air quality impacts is required and will clarify the minimum amount of information required for the air quality assessment. The SPG will follow the Guidance on Land-use Planning and Development Control, as published by Environmental Protection UK (EPUK) and the Institute of Air Quality Management (IAQM).

Chapter 4 Transport Management and Active Travel



4.1 Transport Strategy

Cardiff Council's longstanding vision for transport in the city is for:

"An integrated transport system that offers safe, efficient and sustainable travel for all, where public transport, walking and cycling provide real and desirable alternatives to car travel."

Our priorities to achieve this are:

1. Widening travel choices making it practical for most daily trips to be made by alternatives to the car, such as public transport, walking and cycling;
2. Demand management taking steps to reduce the demand for travel overall, and particularly by car ; and
3. Network management using technology to make best use of the existing highway network, rather than building new roads that would generate more traffic

.

4.1.1 Local Transport Plan

Cardiff is growing and changing, and this brings more journeys and more pressures on Cardiff's transport network. Reducing the number of car journeys made in the city, and promoting the use of active and sustainable modes of travel, are central to Cardiff Council's Transport Strategy and in improving air quality in the city. The LDP sets the target of achieving a 50:50 modal split – this means that 50% of all journeys need to be made by sustainable transport by 2026 in order to accommodate the future development set out in the LDP. Our policies set out in the LDP support the need to secure significant improvements to the public transport and active travel networks in combination with new developments.

Cardiff's Local Transport Plan (LTP) was approved by the Welsh Government in May 2015. The LTP sets out our main transport infrastructure proposals which will support this significant modal shift. The Local Transport Plan recognises the need to improve air quality. Its programme prioritises:

- development of active travel networks to increase walking and cycling for local journeys
- the provision of cycling infrastructure
- the bus network
- reduced speed limits
- reducing congestion
- improving transport efficiency and reliability
- Bus based park and ride.

4.2 Capital City Regional Deal

The Cardiff Capital Region (CCR) City Deal is a programme agreed in 2016 between the UK Government, the Welsh Government and the ten local authorities in South East Wales to bring about significant economic growth in the region through investment, upskilling, and improved physical and digital connectivity.

One of the Cardiff Capital Region (CCR)'s objectives is to connect communities, business, jobs, facilities and services in the area. The CCR Transport Authority, working closely with the Welsh Government, Transport for Wales and others, has been established as a sub-committee by the CCR Cabinet to facilitate the City Deal by coordinating transport planning and investment across the region. The transport improvements underlying the CASAP measures to be assessed later in this report will be fundamental to delivering this objective of CCR.

4.3 Active Travel (Wales) Act 2013

This Act[26] came into force in September 2014 and requires local authorities to map and continuously improve routes and facilities for cycling and walking. Reducing road traffic emissions will be a key aspect of the measures being taken forward and thus the increase in modal shift to active travel will be a key component of the Councils preferred option to achieve compliance.

4.4 Cycling Strategy and Integrated Network Map

The Cardiff Cycling Strategy sets out an ambitious vision to double the number of cycling trips by 2026, from a 9.2% modal share in 2015 to 18.4% in 2026. In order to achieve this vision, it will be necessary to develop a comprehensive network of cycling infrastructure which is suitable for use by people of all ages and abilities, and to work with key partners from employers, retail and schools to ensure that appropriate cycling facilities are provided at destinations and to promote cycling.

[26] Active Travel (Wales) Act 2013

Infrastructure improvements for walking and cycling are planned and prioritised through the Integrated Network Map (INM) as detailed in Figure 8 and is a requirement of the Active Travel (Wales) Act 2013. The INM defines a network of walking routes and cycling routes and a schedule of schemes to improve this network of routes over a 15 year period. In accordance with the requirements of the Active Travel Act, the INM will be submitted to the Welsh Ministers for approval in November 2017 and updated every 3 years.

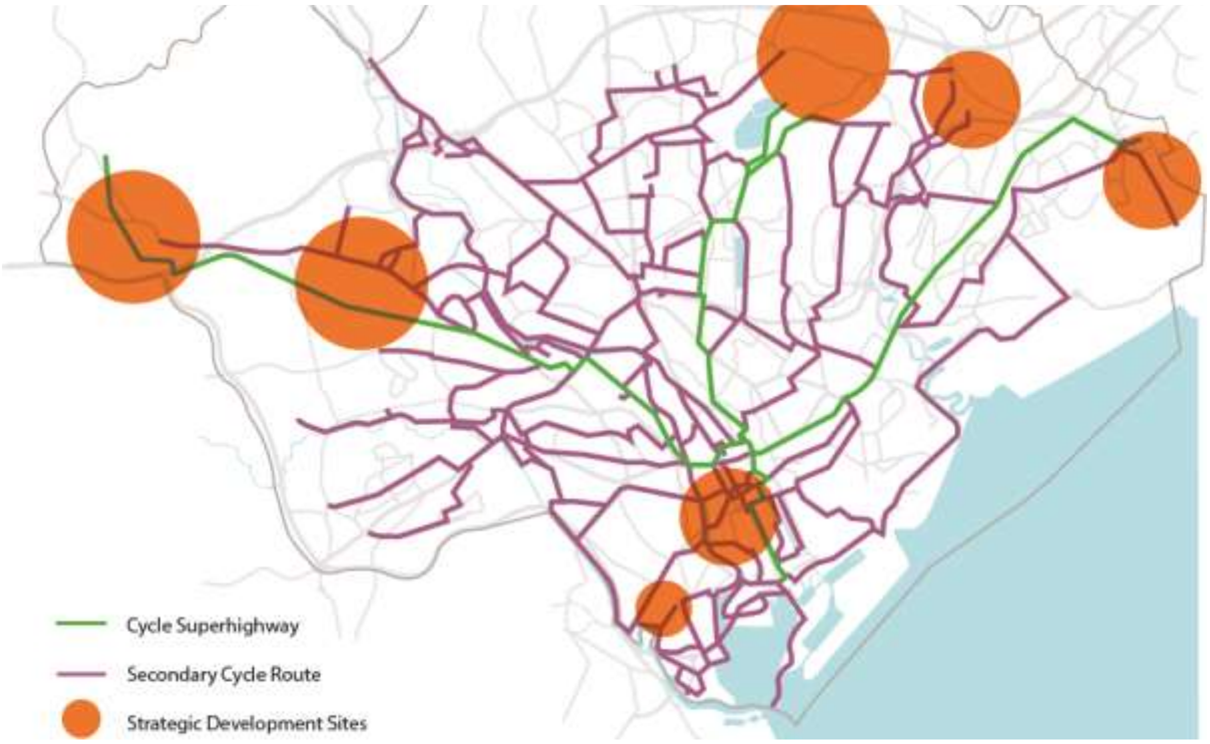
The Cycling Strategy and INM sets out proposals for two new cycle superhighways which will provide high quality cycle routes, segregated from pedestrians and motor vehicles on busy roads, and will connect strategic development sites, existing residential areas, employment sites, the city centre and Cardiff Bay. These will be supported by a network of secondary routes.

4.5 NextBike Scheme

The Nextbike hire scheme launched in Cardiff in March 2018. The scheme is financially funded by Welsh Government and its main objectives are to reduce congestion, free up parking spaces and provide a healthier way to travel around the city.

Since the introduction of the Nextbike scheme in March 2018, the Cardiff scheme has become the UKs most successful[27], with over 150,000 rentals since March. Due to success of the scheme, the amount of available units is set to double with an increase of a further 500 bikes bringing the total number of bikes available to 1,000 by the summer of 2019.

Figure 8- Integrated Network Map



[27] NextBike In Depth Review 2018

4.6 School Active Travel Plans

The Council has a corporate commitment for every school in Cardiff to have an active travel plan by April 2022. Works are ongoing to understand how the Council can best support schools to develop and implement an active travel plan. The aim of an active travel plan is to increase the number of children, parents and staff travelling to school sustainably, in particular increasing walking, cycling and scooting. There are a range of resources, training and programmes available to schools and the ongoing works will identify what actions the schools need to take and access the relevant initiatives and programmes to implement these actions.

4.7 City Centre Transport Improvement Projects

The employment, shopping, tourism and entertainment facilities in Cardiff City Centre attract hundreds of thousands of commuters and visitors each day from across the Cardiff City Region and further afield.

Traffic flows on main routes to and through the city centre generate peak time congestion which causes delays to bus services and can make the area less attractive for pedestrians and cyclists.

Increasing sustainable travel to and through the city centre will be crucial to achieving improvements in air quality. To achieve this, a programme of City Centre Transport Improvement Projects is being developed. Key measures will focus on sustainable transport improvements that will encourage mode shift and contribute to improving air quality levels.

Such transport network improvements will look to incorporate City Centre West, Central Interchange and Eastside City Centre Schemes.

4.7.1 Reducing Congestion

Traffic congestion delays journeys and can damage the environment of the city and its neighbourhoods. Queuing car traffic has a negative impact on air quality. Cutting congestion by reducing the number of journeys made by car will bring air quality improvements as well as reducing costs and journey times for individuals and businesses. Less traffic can also make journeys made by sustainable and active modes of travel easier, for example, by making bus journey times more reliable and providing a more attractive environment for walking and cycling. By managing Cardiff's highway network more effectively, we will make best use of the existing highway in a way which promotes access by sustainable modes of travel.

4.8 Car Clubs

By offering a flexible alternative to car ownership, car clubs can play an important role in an integrated transport network, giving access to a car for short periods without the need to own a private vehicle. Car club provision in Cardiff is set to grow in the short term, helping to reduce the number of journeys made by car and giving access to new, low emission vehicles.

4.9 20 MPH Zones

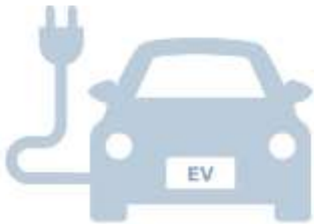
CC introduced a 'signs only' 20 miles per hour (mph) limit in the Cathays/Plasnewydd area in March 2014, as part of a two-year pilot project. Following the pilot, a commitment was made to look at how 20pmh limits might be more widely applied in Cardiff. It was determined that the installation of 20 mph limits in residential streets would support the general consensus that lower speed limits in residential areas can:

- improve air quality in terms of particulate matter exposure;
- improve the liveability of the city by reducing car use for local trips;
- make it easier to cross roads and access local facilities – especially for children and the
  elderly;
- improve the environment for walking and cycling resulting in greater levels of physical activity.

A wider future rollout of 20mph limits is underway in residential streets in areas around the city centre. The installation of 20 mph limits will complement the ongoing installation of school safety zones delivered through the on-going Safe Routes to School programme.

4.10 EV Infrastructure

There is a growing demand for, and need to support, a shift from traditional fossil fuels for residual motorised transport to more sustainable forms of clean, renewable energy, particularly with the commitment made by the UK government to ending sales of new petrol and diesel cars from 2040. Although this activity is largely led by private sector vehicle manufacturing markets, there is also a clear role for the Council in facilitating, championing and preparing for this transition.



A feasibility study reviewing best practice, the market and funding streams will inform a decision on the best option for the city. Locations for EV charging will be considered alongside the rollout of additional car club vehicles in the authority and is seen as vital in encouraging the use of more environmentally friendly modes of transport including Low Emission Vehicles. It is anticipated that a pilot will be undertaken of an EV charging system within 2018 that will contribute to the understanding of the potential of EV technology for Cardiff.

In 2018 Arcadis Consulting (UK) Ltd supported by Zero Carbon Futures (UK) Ltd were commissioned by Cardiff Council to prepare a feasibility study to explore how electrically powered Ultra Low Emission Vehicle (ULEV) charging points could be integrated across the city of Cardiff. As the market share of ULEV is growing and is forecasted to increase significantly over the coming decades, it is critical that the necessary charging infrastructure is provided to facilitate this growth, in order to support a cleaner transport system across Cardiff.

4.11 Low Emissions Transport Strategy

In 2018, Council approved the works to develop a Low Emission Transport Strategy. The Low Emissions Transport Strategy is focussed on the Council's responsibilities and aspirations in dealing with this significant public health issue by supporting a transition away from fossil fuels for transportation. It is also aimed at encouraging key partners in the City to consider similar actions. The Strategy forms a key strand of the Clean Air Strategy for Cardiff, together with developing transport policy and other emerging actions.

This strategy has been based on a series of background studies and discussions with major stakeholders and leaders in the field of low emission transport. This has helped to identify key opportunities for the Council to grasp. Many of these are direct actions addressing the delivery of routine services, but it is also clear that the Council has a wider leadership role that could help to stimulate change in the city and region. The strategic vision is therefore to position the Council as a "catalyst for change", proactively addressing city wide Air Quality challenges. The areas of particular focus are on:

- Facilitating and speeding up a pathway to zero emission transport;
- Using our procurement power to instigate change and provide broader market confidence;
- Engaging with and supporting local innovation; and
- working with partners to secure the best Circular Economies for the City and for Wales.

4.11.1 On Street Residential Charging Points

The Council has been successful in obtaining a bid from the Office of Low Emission Vehicles (OLEV) 36 charge points in 21 locations across the city and accessible to the public by 31st March 2019. The Council will aim to submit a further bid in 2019/20 to further increase the network of residential charging points.

In addition to the above the Council will also be launching a rapid charge pilot with a commercial provider to assess the viability of undertaking a wider implementation project.

4.11.2 Electric Charging Points at Council Facilities

The Council has made progress in terms of increasing electric charging infrastructure at four main employment hubs. It has been agreed that in 2019/20 for 8 electric vehicle chargers each at County Hall, Lamby Way, Wilcox House and Coleridge Road (i.e., total of 32 chargers).

In conjunction with this the proposals are in place for the Council to fund the hire lease costs of 56 new EVs in 2019/20 (replacing existing petrol/diesel vehicles) and 37 vehicles in 2020/21.

4.12 Freight and Commercial Transportation

The M4 in Cardiff and South East Wales is a strategic motorway network in the UK and is a hub for major logistics and distribution companies. Consequently, the number of HGVs/LGVs on the road network contributes to overall air pollution. Source apportionment results detailed in **Error! Reference source not found.** indicates that HGV/ LGV movements are the second most contributing source to monitored NO_2 levels.

Recent years have seen an increase in the number of light goods vehicles (LGVs), which may be attributed to an increase in internet sales, home deliveries and growth in the independent service sector and trades.

The commercial sector can be difficult to influence, but they understand the need to reduce their carbon footprint, improve their "green" credentials and be socially responsible for the impact they have on the environment.

The need to support and improve freight is highlighted in Cardiff's LDP and LTP. Policy KP8 Sustainable Transport emphasises the support of freight movement by rail or water and the need to manage freight movements by road and minimise their impacts. The plans accentuate CC's commitment to pursue opportunities to implement infrastructure improvements for other transport modes including facilities for freight.

Through this strategy Cardiff Council will consider the establishment of a Freight Quality Partnership (FQP). By means of such partnerships industry and local government can work together to develop more efficient, safer and cleaner means of local goods distribution. CC will look to adopt the available free advice from the Freight Best Practise programme, funded by DfT, covering topics such as saving fuel, developing skills, equipment and systems, operational efficiency and performance management.

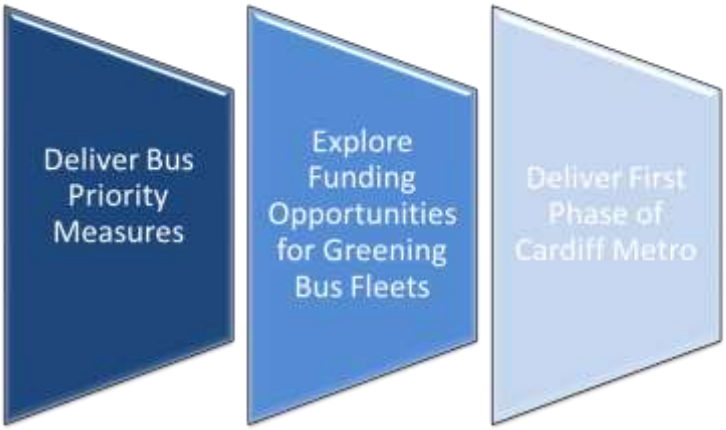
There are three main objectives associated with a FQP;

- **Environmental:** to protect and enhance the built and natural environment, e.g. by improving air quality, contributing to Greenhouse Gas reduction targets and reducing noise pollution.

- **Economic:** to support sustainable growth and regeneration in appropriate locations, e.g. by increasing competitiveness of local businesses, improving supply chain efficiency, reducing congestion, and investing in supply chain infrastructure.

- **Societal**: to protect communities and support the needs and aspirations of citizens e.g. by reducing disturbance from vehicles, improving safety and enabling efficient access to goods and services.

Chapter 5 Public Transport



Public transport has a key role to play in improving air quality by helping to reduce the number of car trips made to and within the city. Use of public transport is also known to increase physical activity levels, helping to keep our population healthy.

Public transport has a key role to play in improving air quality by helping to reduce the number of car trips made to and within the city.

5.1 Buses

Bus travel has an important role to play in reducing the number of journeys made by car. We are working to make bus travel an attractive and practical option for more people by providing infrastructure to help bus services beat the traffic queues and improve their reliability and frequency.

Bus lanes have been installed on a number of main roads into the city including the A470, A4119 and A48. Cardiff has 13.94km of bus lanes. 400m of bus lane can give each bus a time advantage of 5 minutes or more over general traffic on the approach to junctions and improve the ability of bus drivers to meet timetables (Cardiff 2014 Regional Bus Lane surveys).

However, it is also important that the buses used in Cardiff are as clean and low emission as possible. We will continue to work with Cardiff Bus and other local/ regional operators to identify measures to provide low emission bus fleets operating in Cardiff.

Our priorities for bus travel in Cardiff include:

- Developing a new bus interchange as part of the major redevelopment of Central Square;
- Working with bus operators to identify and develop an expanded city bus network, including new cross-city and local routes;
- Work with operators to increase the number of buses where bicycles can be taken on board, to encourage mixed active travel to be used as part of longer journeys;

- Developing new bus park and ride facilities at M4 Junction 33 and other appropriate locations in Cardiff and neighbouring areas to reduce the number of cars driving into the city;

- Making bus services faster and more reliable by providing bus priority measures on strategic bus corridors to help reduce bus journey times, improve journey time reliability and make bus travel a more attractive alternative to the car for a greater range of journeys; and

- Investigating opportunities for the development of a green technologies bus fleet.

5.1.1 Cleaning the Bus Fleet

Data provided by Cardiff Bus indicates 140 Cardiff Bus movements per hour along Westgate Street, whereby only 26% of these movements are made by Euro 6 category vehicles.

The conversion of Cardiff bus vehicles to Euro 6 equivalent or better will have an immediate positive impact on air quality levels, particularly in the City Centre AQMA. Real world testing of Euro 6 diesel buses demonstrates a 95% reduction in NOx emissions compared with Euro 5. The improvements that could be made in air quality on Westgate Street is evident from the pollution source apportionment as detailed in Figure 9, which shows that buses/ coaches account for nearly 40% of the pollution on Westgate Street.

Figure 9- NO_2 Source Apportionment (Westgate Street)

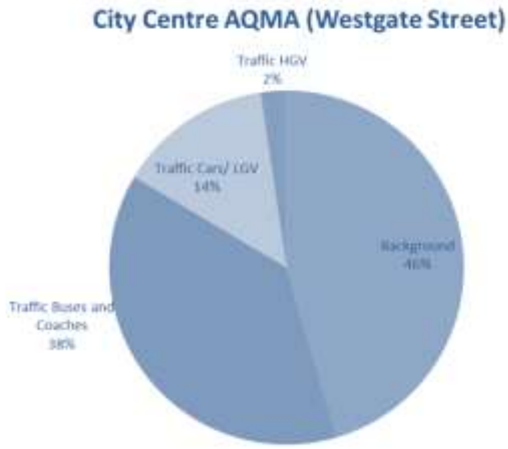


Table 5 summarises the current Cardiff Bus fleet and associated Euro Emission Standard classification. Table 6 summarises the hourly Cardiff Bus service fleet movements along Westgate Street and Euro Emission Standard Classification

Table 5 Euro Standards of Cardiff Bus

Cardiff Bus- Fleet Euro Standard (30th June 2018)		
Euro Standard	Number	%
Euro 3	95	42
Euro 4	44	19
Euro 5	50	22
Euro 6	40	17

Table 6 Cardiff Bus Fleet Hourly Breakdown on Westgate Street

Cardiff Bus- Fleet Euro Standard (Westgate Street 25.10.17)		
Euro Standard	Number	%
Euro 3	72	51
Euro 4	17	12
Euro 5	15	11
Euro 6	36	26

Cardiff Bus representatives have determined that 41% (94 vehicles) of the Cardiff Bus fleet would qualify for a Euro 6 retrofit programme.

In addition to the suggested retrofit programme, in 2018 SRS along with Cardiff Council's Transport team collaborated with Cardiff Bus to devise a bid application for the Ultra-Low Emission Bus (ULEB) fund made available by the Office for Low Emission Vehicles (OLEV). In February 2019 the bid application was deemed successful.

The proposal draws links between the air quality management areas (AQMAs) identified under the LAQM regime, as well as the issued direction from Welsh Ministers which targets Cardiff on the regional scale highlighting non-conformities in association with European Directives. Therefore linking the two together; due to the heightened profile of air quality and its potential adverse impact on public health, given Cardiff's Local Air Quality Management scenario, as well as its regional air quality concerns it is imperative that short term measures, such as increasing the uptake of low emission buses are implemented as soon as possible to start the process of achieving compliance with the air quality objectives.

The bid application has secured contributable funding for a total of 36 full electric buses that would be introduced to the Cardiff Bus fleet over a three year cycle. The vehicles will be introduced to three specific routes (27, 44/45 & 49/50). These routes will lead to a positive impact on air quality levels, especially within the City Centre AQMA. The introduction of the electric buses would form part of a cascade programme whereby Euro 3 standard buses would be offset from the fleet completely, therefore improving the overall fleet composition.

Tables below highlight the Cardiff Bus Fleet matrix in 2021 with the implementation of the full electric vehicles. The datasets show that the percentage of Euro III buses would reduce from 41% to 26%.

Table 7 Cardiff Bus fleet with ULEB funding (2021)

Cardiff Bus- Fleet Euro Standard (2021)		
Euro Standard	Number	%
Euro 3	59	26
Euro 4	44	19
Euro 5	50	22
Euro 6	40	17
Full Electric	36	16

It is important to highlight that the Council will continue to work with Cardiff Bus and other regional bus operators to continue making improvements in the composition of the bus fleets operating on the Cardiff road network. Ideally such work will focus on shifting to even greener bus types, such as hybrids, full electric and even hydrogen, rather than retro fitting older buses. Securing a greener bus fleet will be a key action in the strategic measure to **Increase the Uptake of Sustainable and Active Travel.**

5.2 Cardiff Capital Regional Metro

The Cardiff Capital Region Metro proposed by Welsh Government is likely to comprise a combination of rail-based and bus-based rapid transit routes linked through interchanges and using the same network brand and integrated ticketing system.

We will continue to work closely with Welsh Government and other partners to support delivery of the Valley Lines Electrification programme and the design of future extensions to the Metro network through new rail and bus-based routes and improved interchange facilities.

5.3 Bus Travel to Schools

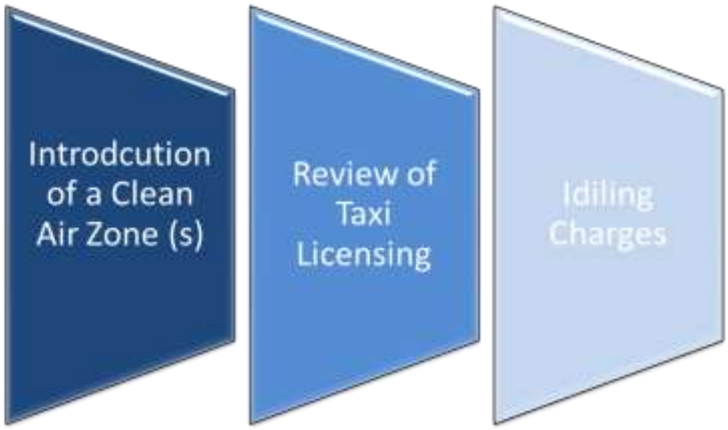
Where Cardiff Council provides buses for school transport, vehicle age and emission ratings are considered as part of a quality assessment through the procurement process. Cardiff Council will continue to ensure that school buses are of the highest possible standard and that evolving requirements in relation to quality are taken into consideration.

5.4 Trains

6% of journeys to work by Cardiff residents are made by rail and passenger numbers across the city and the wider region have grown significantly in recent years. Cardiff Council works closely with key partners, including Welsh Government, rail operators and Network Rail, towards improving and developing the rail network. The new Wales and Borders rail franchise offers the prospect of new rolling stock, increased capacity and frequencies to the meet the ever increasing demand for rail services and allow for further modal shift to rail based journeys.

Cardiff Council will work with operators to increase the number of trains where bicycles can be taken on board, to encourage mixed active travel to be used as part of longer journeys.

Chapter 6 Additional Regulatory Measures



In addition to the above measures, there are also regulatory measures that could be considered by the Council in order to assist in improving air quality and these are discussed further in this Chapter.

6.1 Clean Air Zones

Currently in Wales there is no finalised Clean Air Zone (CAZ) framework, with only a draft framework published by Welsh Governments draft[28] in 2018. In this framework Welsh Government have defined a CAZ as

> *"A geographical target area where a range of co-ordinated actions are applied with the purpose of ensuring, in the soonest time possible, a significant reduction in public and environmental exposure to harmful airborne pollutants from all sources.".*

Evidence shows that Clean Air Zones can deliver substantial benefits across large populations (NICE2017).

Welsh Government further stated that the designation of a CAZ is seen as a much stronger commitment to achieve real improvements in air quality in an area than the designation of an Air Quality Management Area (AQMA) under the Environment Act 1995, which Local Authorities are required to do wherever they find non-compliance with one of the national air quality objectives. Declaring an AQMA triggers a requirement to produce a local air quality action plan "in pursuit of the achievement of air quality standards and objectives in the designated area".

Welsh Government states that a CAZ should:

- consider the full range of sources of air pollution and environmental noise (not restricted to road use);
- apply targeted action in a specific area to improve air quality and soundscapes and thereby improve the health and well-being of the population
- aim to reduce all types of airborne pollution, including, but not restricted to, NO_2 , , particulate matter (PM) and environmental noise, as well as greenhouse gases such as carbon dioxide (CO2)
- ensure that the environmental improvements which are achieved are long-lasting; and

[28] https://gov.wales/sites/default/files/consultations/2018-04/180424-clean-air-zone-framework-en.pdf

• act against potential increases in pollution arising through population growth, new development, or changes in land or building use.

The Welsh Government's draft framework differs significantly from the framework developed by Defra for English Local authorities specifically in that it does not set Class standards for vehicles categories, but only sets emissions standards that vehicles need to achieve in order to be compliant with a CAZ. Table 8 sets out the vehicle emission standards that vehicles are required to meet to comply with any CAZ in Wales.

Table 8 - Vehicle Emission Standards for CAZs in Wales

Vehicle type	Euro Category	Euro Emission Standard
Bus and Coach	M3 (GVW over 5,000kg and more than 8 seats in addition to the driver) M2 (GVW not exceeding 5,000kg, ref mass exceeding 2,610kg and more than 8 seats in addition to the driver)	Euro VI (with retrofitted diesel engines meeting Euro VI by using the Clean Vehicle Retrofit Accreditation Scheme(CVRAS))
Minibus	M2 (GVW not exceeding 5,000kg, ref. mass not exceeding 2,840kg and more than 8 seats in addition to the driver)	Euro 6 (diesel) Euro 4 (petrol)
Taxi and Private Hire	Passenger vehicle with up to 8 seats in addition to the driver	Euro 6 Euro 4 (petrol) (diesel)
HGV	N2 (GVW over 3,500kg and ref. mass over 2,610kg) N3 (GVW over 5,000kg)	Euro VI (with retrofitted diesel engines meeting Euro VI by using the CVRAS)
Large van	N1 (GVW not exceeding 3,500kg and ref. mass not over 1,305kg but not exceeding 2,840kg) N2 (GVW over 3,500kg and ref. mass not exceeding 2,840kg)	Euro 6 (diesel) Euro 4 (petrol)
Small van and light commercial	N1 (GVW not exceeding 3,500kg and ref. mass not exceeding 1,305kg)	Euro 6 (diesel) Euro 4 (petrol)
Cars	Passenger vehicle with up to 8 seats in addition to the driver	Euro 6 (diesel) Euro 4 (petrol)
Motorcycles and mopeds*	Not applicable	Euro 4

*Vehicle types include powered cycle, two and three-wheel moped, on-road quad, quadrimobile, two-wheel motorcycle (with and without sidecar), and tricycle.

In order to consider the implementation of any CAZ it is anticipated that a detailed feasibility study would be required in order to assess the extent/ area that such a zone should cover and the appropriate charging mechanisms that any scheme would implement. Any CAZ would need to be proportionate in terms of the desired air quality improvements in relation to the poetical distributional impacts that such a scheme may have on the socio-economics of the location and surrounding areas.

6.2 Urban Green Infrastructure

Urban Green infrastructure (GI), when designed and implemented correctly can lead to improved air quality on a local scale. GI has the ability to control pollution dispersion and deposition, and therefore is a useful tool to be used in urban environments to mitigate poor air quality. As well as improved air quality conditions, urban green infrastructure also provides benefits such as less heat stress, management of storm waters and a reduction in energy consumption and noise pollution.

Forms of GI include trees, hedges and bushes, green walls and green roofs.

-Trees and other GI influence wind flow. The combination of buildings, trees and gardens creates a rough surface area due to the variation in height, creating turbulence that increases mixing and pollutant dispersion (Figure 11).

- Dependant on the location of a pollution source i.e. Vehicle, trees located in narrow, enclosed streets "Street Canyons" can have both positive and negative impacts on air quality. When a pollution source is located within the street canyon, a tree's canopy leads to reduced mixing and therefore fumigation. When a pollution source is located outside a street canyon a tree's canopy acts as a barrier aiding improved air quality concentrations (**Error! Reference source not found.**).

-Hedges can be used as a barrier to increase the pathway between a pollution source and sensitive receptor (person), which increases mixing and reduces the pollutant concentration (**Error! Reference source not found.**).

Figure 10

Figure 11

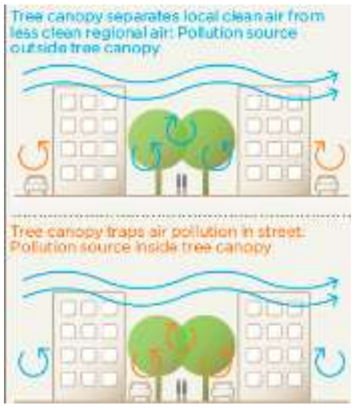


Figure 12

In January 2018, CC collaborated between different departments and produced a successful application bid to utilise funding made available by Welsh Government, known as Green Infrastructure Grant Funding Scheme. The requested funding is being used to enable a project that focusses on the benefits of trees and planting to the city, with a specific emphasis on methods of addressing air quality issues.

In addition to the funding received via the Green Infrastructure Grant Funding Scheme, Cardiff Council has also successfully acquired funding via the Landfill Communities Fund. The funding is being utilised to support a Green Walls project for Tredegarville CIW Primary School.

Tredegarville CIW Primary School is located in a very urban high rise setting in Cardiff city centre and as a result, the school provides its pupils with very little access to green space. However, the school is enthusiastic about improving this situation through developing the green environment at its site.

There are particular concerns regarding air quality in the vicinity of the school, arising both from traffic and construction. Given that green walls (also referred to as ‘green screens’) have been used to improve air quality in cities such as London and Birmingham, a proposal is being put together for green walls to be installed in Cardiff. Such a project could bring together the joint ambitions around green spaces/biodiversity and air quality through making use of a passive/nature based solution.

6.3 Taxi Licensing

6.3.1 Background

Hackney carriage and private hire services are a vital aspect of the transport network in Cardiff. They are essential for many passengers with disabilities and play an important social role in enhancing the public transport system. However, they are also a source of road traffic derived emissions causing air pollution, especially in the City Centre.

The Licensing Authority of Cardiff Council regulates hackney carriage and private hire drivers, vehicles and operators and set the conditions that licence holders must adhere to. There are currently **2,261** hackney carriage/private hire drivers, **902** hackney carriages and **1,150** private hire vehicles.

Since 2009 there has been a cap in place on the issuing of new hackney carriage licenses. The primary difference between the types of vehicle is that hackney carriages are able to use taxi ranks and can be hailed from the roadside, whereas private hire vehicles can only be booked through a licensed operator.

Vehicles must be tested by a Cardiff MOT station either annually or bi-annually, depending on their age. This consists of an MOT test plus an additional compliance test that inspects items such as the taxi roof light that would not otherwise be tested as part of an MOT test. Furthermore, Licensing Officers also investigate complaints regarding the standard of vehicles and routinely carry out spot checks. If required they have powers to suspend a licence until they are satisfied with the vehicle’s condition.

Currently there is no minimum emissions standard that vehicles have to adhere to and, thus vehicles may be licensed up to 10 years old; however, the age restrictions may be waived if the vehicle complies with the authorities’ ‘exceptional condition' policy that was introduced in 2016. This requires the vehicle to be inspected annually by a Licensing Officer to ensure if meets the required standard.

6.3.2 Cross Border Issues

Cross-border hiring is an issue facing the hackney carriage/private hire trade. This is where vehicles licensed by one authority carry out private hire work in another authority area. Although there are over 340 licensing areas across England and Wales, Licensing Officers have no cross-border enforcement powers. This means that although Cardiff can impose conditions on the vehicles which are licensed in Cardiff, enforcement officers have no powers over the vehicles licensed by other authorities which may be working in Cardiff.

This has created a situation whereby applicants may choose to licence in an area that has less stringent conditions, but operate predominantly in Cardiff. To help combat this, some Welsh licensing authorities have introduced 'intended use' policies that hackney carriage licenses to show a bone fide intention to trade predominantly in the area where they are licensed. However, this only applies to hackney carriages and unless all authorities in England and Wales adopt an intended use policy, applicants can still choose an authority without one.

Despite the growth and evolution of the industry, the main legal framework governing taxi services has not undergone any significant reform for nearly 200 years.

6.3.3 Welsh Government Taxi and Private Hire Vehicle Licensing In Wales Consultation 2017

In 2014, the Law Commission for England and Wales published its proposals for the reform of the legislative framework governing the licensing of taxis and private hire vehicles in England and Wales. Following commencement of relevant provisions of the Wales Act 2017, licensing of taxis and private hire vehicles will be a matter within the legislative competence of the National Assembly for Wales.

Welsh Government considered the proposals for the framework for licensing taxis and private hire vehicles put forward by the Law Commission, for the purpose of bringing new arrangements into effect in relation to Wales, and recently completed a consultation on these proposals.

One proposal detailed in the consultation would be the introduction of **national standards** for all taxis and private hire vehicles, set by the Welsh Ministers, with the power for local licensing authorities to set additional standards where it is appropriate to do so.

This may have benefits for improving air quality in Cardiff, as **if** these standards take into consideration of vehicles having minimum emission standards for taxis or prioritising/ incentivising electric/ zero emission vehicles, then the drivers may be encouraged to upgrade their vehicles which could see a reduction in the number of older more polluting vehicles on the roads. As a licensing authority these are measures that Cardiff could self-implement as part of additional standards. This strategy will recommend that such measures are considered by the Licensing Committee, depending on the outcome of the Welsh Government consultation. The Welsh Government is expected to publish a draft bill in 2018.

In their response to the consultation, the Shared Regulatory Service highlighted the issue of vehicles idling within the city centre and suggested a possible solution of additional 'holding areas' on the fringes of town centres for vehicles to wait until they are booked electronically. These areas could be tailored specifically for taxis, including charging points for the eventual move to electric vehicles and could be the catalyst for taxis to embrace electric vehicles.

6.3.4 Proposals

On the 5th March 2019 the Public Protection Committee agreed for Shared Regulatory Services to consult on the proposals to amend the Council's taxi licensing policy which would see the introduction of new emissions and age requirements for the granting of new licenses and/ or change of vehicle applications on new existing licenses. **The proposals[29] would require that any vehicle included on the application for a new grant is a minimum Euro 6 emission standard (petrol and diesel) as part of the license application. The same emission standard would also apply for any change of vehicle on an existing license.**

Following the detailed consultation on this proposal the Public Protection Committee will be asked to approve the revisions of the Councils licensing policy, with an implementation date to be agreed. Whilst there is no direct cost the Council for implementing the revised license conditions, it could be argued that Council's new taxi strategy to set age and emissions criteria for licensing for private hire and hackney carriages could place a financial burden on drivers and operators licensed within Cardiff. This burden is not faced by taxis licensed outside of Cardiff and they are free to compete for trade alongside Cardiff licensed taxis. This potential could see Cardiff taxis placed at a financial disadvantage.

In order to redress the balance, the Council will assess measures in detail that will assist taxi operators with making the switch to newer, more efficient vehicles. The economic assessment will include for the provision of mitigating measures for the taxi trade, in terms of a grant scheme to assist with purchase of OEV/LEVs.

It is proposed that Cardiff Council develop a similar grant scheme to those outlined by other Councils. Funding for the scheme would be facilitated via the acquired funding allocated in support of WG's legal direction and required feasibility study.

Cardiff Council would ensure that the grant scheme remains in place until such a time as all vehicles, are upgraded. Further it is possible that the licensing policy could be revised further in the future as the report being taken to the Public Protection Committee states the following:

- A consultation on whether to require all hackney carriage and private hire vehicles licensed for the first time to be ULEV from January 2021;

[29] Public Protection Committee 5th March 2019 Item 5 Update To The Age, Emission And Testing Requirements Of Hackney Carriage And Private Hire Vehicles

- A consultation on whether to require all existing hackney carriage and private hire vehicles to be ULEV from January 2025.

Therefore a longer term grant scheme may need to be considered should the Council implement further policy revisions. Further the Welsh Government's current consultation on Improving Public Transport[30] states that Welsh Government proposes that a 'national standard should apply which specifies requirements for the vehicular emissions of taxis and PHVs' and thus Welsh Government may need to consider a wider national scheme to support any such policy.

6.4 Vehicle Idling Charges

An idling engine can produce up to twice as many exhaust emissions as an engine in motion. This can affect the air quality of the surrounding environment and the air we breathe.

Under the Road Traffic (Vehicle Emissions) (Fixed Penalty) (Wales) Regulations 2003 Cardiff Council has the power to implement 'no vehicle idling' areas, particularly where groups congregate (such as outside schools, hospitals and care homes, and in areas where exposure to road-traffic related air pollution is high, i.e., in AQMAs.

The Council will therefore assess the feasibility and likely benefits of introducing No Vehicles Idling Areas.

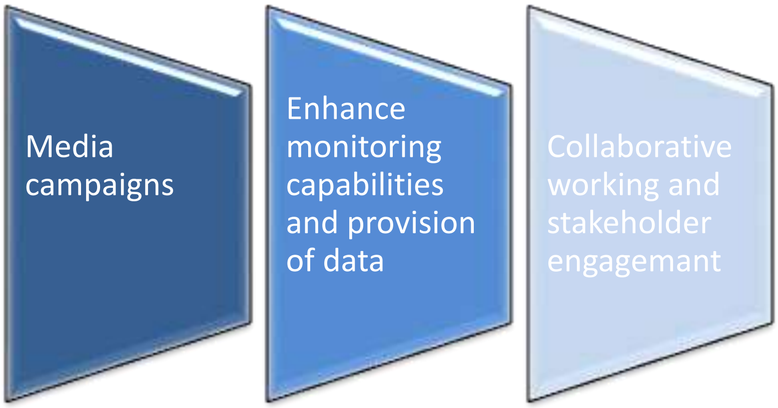
6.5 Review of Car Parking Charges and Residential Permitting Charges

The Council has powers to review the amount it charges residents for on road parking permits. An assessment should be made of the potential impact of introducing a sliding scale of permit charges based on the emission standards of vehicles, which would see a significant reduction in permit costs for EV/0LEVs, in order to encourage and expedite the update take of such vehicles. Such measures have already been implemented in a number of Local Authorities in England.

Similar measures will also be considered at Council Car Parks and on Street Parking locations, whereby the most polluting vehicles would be charged a premium parking rate.

[30] https://beta.gov.wales/sites/default/files/consultations/2018-12/improving-public-transport_0.pdf

Chapter 7 Influence and Deliver Transport Behavioural Change



Behavioural change is one of the most important elements the Council will need to take a lead on to help achieve the needed increase in active and sustainable transport to deliver the 50:50 modal split target set out in the LDP. A major aspect of this will be delivering an effective communications strategy focused on promoting actions that all stakeholders including the council, businesses and the general public can take to instigate this behavioural change.

7.1 Communications

The communication strategy will need to focus on promoting and marketing the wider health and environmental benefits of tackling air quality. It is essential that the key messages clearly show how:

- air pollution has a direct impact on the lives of residents and visitors to Cardiff;
- individual actions can affect air quality; and
- making personal changes will benefit an individual's health and wellbeing, as well as helping make Cardiff a more attractive and sustainable place in which to live and work.

To support this, we will produce a local public awareness campaign, with input from the Welsh Government and Public Health Wales with a focus on:

- providing technical scientific evidence on the Council's website and the Welsh Air Quality Forum websites;
- promoting air quality and engaging with government and business audiences through seminars, social media and conferences;
- communicating with the public about how to reduce the impacts of air pollution by travelling using alternatives to the private car, particularly on days when air quality is poor. This will include using variable message signs and other forms of advertising on our road network as well as other media, including social media;
- working with Welsh Government and other partners to integrate information about air quality into educational resources for to young people;
- improving the air quality information that the Council can provide by increasing our ability to undertaken real-time air quality monitoring.

7.1.1 Car-Free Day

Car- Free Day is considered an excellent opportunity to endorse air quality awareness. Specifically CC has shared great success promoting Car-Free Day events. In May 2018, CC organised a car-free day event in the city's central area. The event coordinated with the HSBC UK Let's Ride event and on street entertainment.

Footfall in the city centre was up by 28% compared with the same day last year, with 125,173 people recorded in the city centre on Sunday compared with 90,005 people on Sunday May 14^{th}, 2017. Organisers of the event have said that 5,000 people took part in the HSBC UK Let's Ride event, with a further 5,000 people taking part in the entertainment.

As well as providing a carnival atmosphere for the public to enjoy, the idea of Car Free Day was also to monitor air quality and traffic flow in the city centre.

With the increase in footfall in the city centre, the Council was also keen to monitor traffic flows on specific roads that were still open on the periphery of the city centre closure. The results showed a 25% reduction on Newport Road; a 16% reduction on Central Link; a 22% reduction on Cathedral Road; an 11% reduction on Bute Street; an 8% reduction on Clare Road; a 30% reduction on Moira Terrace; an 8% reduction on Fitzalan Place and a 45% reduction on North Road.

City Centre Footfall- City Centre footfall cameras recorded a 28% increase in pedestrian footfall versus the previous year (cameras are located on Queen St, High St, St Mary Street and The Hayes)

Bus Use- Cardiff Bus reported that they had more passengers than they would on a normal 'event day'. Stagecoach recorded a +5% increase in passengers versus a normal Sunday (these figures suggest that most people walled or cycled).

The summary of air quality monitoring;

Shared Regulatory Services (SRS) on behalf of Cardiff Council undertook a study to examine levels of air quality within Cardiff's City Centre in order to quantify the impact that the car-free day event on Sunday 13^{th} May 2018 would have on the main traffic derived pollutant of concern nitrogen dioxide (NO_2). It was anticipated that levels of NO2 would reduce due to the restriction of vehicles and thus the study was undertaken in order to demonstrate and quantify this likely reduction.

Air Monitors Ltd supplied SRS with three near real-time indicative air quality monitors (AQ Mesh Pods). AQ Mesh pods measure gases, in this case nitric oxide, nitrogen dioxide and ozone using electrochemical sensors powered by Lithium batteries. The data from the pod is pushed to a cloud server where it is corrected for temperature, pressure and relative humidity as well as cross gas interference. To verify the performance of the gas sensors the units ran alongside a reference station and local scaling factors were derived and used to characterise the sensors. This then enables direct comparison of the data between the pods and the reference station.

In order to give a detailed understanding for the impact to air quality, levels were recorded before and after car- free day to enable a comprehensive comparison between normal baseline conditions and car-free day. The monitors were cited at their specified locations on Friday 4^{th} May 2018 and decommissioned on Thursday 24^{th} May 2018.

The monitors were located at locations situated on specific network routes influenced by the day's event;

- Westgate Street
- Castle Street/ Duke Street
- Stephenson Court, Newport Road

When comparing Sunday 20th May to Car-Free Day event 13th May, the daily average reduction for NO_2 was as follows;

- Duke Street/ Castle Street- 86.52%
- Stephenson Court on Newport Road- 35.80%
- Westgate Street- 84.20%

7.2 Collaboration with other Stakeholders

Recent policy guidance from Welsh Government on local air quality management stressed that the need to work actively with internal and external partners to reduce air quality (ref http://gov.wales/docs/desh/publications/170614-policy-guidance-en.pdf). Stakeholders can include both the private and public sector and the council will need to work with them to support the aim of this Strategy and help share and adopt best practice within their organisations. The Council will need to work closely with others with an interest in air pollution to ensure a joined up approach using their environment, health and transport expertise. For example, encouraging physical activity to improve health and work to improvement to the natural environment will complement active travel initiatives and can help reduce traffic congestion, pollution and noise.

It is important to see improving air quality as a corporate responsibility for both the private and public sector. Organisations such as the Council, NHS, NRW, Public Health Wales etc can play an important role in improving air quality through both how they operate and through influencing their employees' behaviour. Improving air quality should, therefore, be considered an important part of corporate responsibility and sustainability.

7.2.1 Proposals

Working initially through Cardiff Public Services Board, a Healthy Travel Charter for Cardiff has been developed with major public sector employers which will be launched in April 2019. Signatories to the Charter make 14 commitments on improving access to active and sustainable travel for staff and visitors to their main sites, and jointly commit to three targets namely:

- Reduce the proportion of commuting journeys made by car;
- Increase the proportion of staff cycling weekly; and
- Increase the proportion of vehicles used for business purposes which are plug-in hybrid or electric.

The Charter will be signed by 11 public sector organisations at launch, employing over 33,000 staff, with additional public and private sector organisations subsequently invited to sign up to the Charter.

Chapter 8 Assessment of Actions to Deliver Strategic Measures

8.1 Summary of Actions

The previous Sections outlined strategic measures that the Council are currently working towards in order to improve air quality in Cardiff.

Table 10 summarises current and envisaged individual actions that will enable the strategic measures to be implemented and provides a qualitative assessment of the actions in terms of their potential impact on air quality, cost and time scales for implementation. The qualitative appraisal identifies whether the actions are likely to have a direct impact on the existing AQMAs in Cardiff.

8.2 Delivering Legal Compliance

Whilst the overall aim of this strategy is to deliver improvements in Air Quality across Cardiff to protect and improve public health, another significant driving factor is to deliver compliance with the EU Ambient Air Quality Directive (2008/50/EC), in the shortest time possible, as ruled by the UK High Court in 2016.

As previously discussed CC has been identified by Defra for having road links with exceeding annual average levels of NO_2.

The detailed UK plan for tackling roadside nitrogen dioxide concentrations provides some guidance on local measures and specifically states in reference to Cardiff; "***Where alternative local measures are suggested, to be effective they must be capable of achieving compliance within the same amount of time, or sooner, than a Clean Air Zone with access restrictions."***

Under Part IV of the Environment Act 1995, Section 85(7), WG has issued formal direction to Cardiff Council to address its air quality concerns outlined by the projections modelled and illustrated within the UK detailed plan. The direction has been governed by Welsh Ministers who have determined that the direction is necessary to meet obligations placed upon the United Kingdom under the EU Ambient Air Quality Directive (2008/50/EC). The direction outlines specified activities that are required to be completed by specified deadlines.

- **Initial Scoping Proposals (Deadline 31st March 2018)-** Setting out the proposed approach to the feasibility study and including scope of work, governance, resourcing, procurement approach, indicative costs and timings.
- **Initial Plan (Deadline 30th September 2018)-** Setting out the case for change and identifying, exploring, analysing and developing options for measures which the local authority will implement to deliver compliance in the **shortest time possible,** with indicative costs for those options.
- **Final Plan (Deadline 30th June 2019)-** Identifying in detail the preferred option for delivering compliance in the shortest possible time, and including a full business case setting out value for money considerations and implementation arrangements and timings.

As part of the UK detailed plan, those identified local authorities are required to undertake a feasibility study in accordance with the HM Treasury's Green Book approach, to identify the option which will deliver compliance with legal limits for nitrogen dioxide in the area for which the authority is responsible, **in the shortest possible time.**

The feasibility study will look to examine the likelihood of the council's proposed measures achieving compliance with the EU & UK Ambient Air Quality Directive Limit Values for NO_2, and if so, when a date of compliance is envisaged. The expected date of compliance for these proposed measures must be cross referenced to benchmarked compliance date expected for the introduction of a charging Clean Air Zone (CAZ). If compliance is not likely to be expected prior to the anticipated CAZ benchmarked compliance date, a CAZ will be the agreed option.

If compliance is not likely to be expected prior to the anticipated CAZ benchmarked compliance date, a CAZ will be the preferred option. Subsequent modelling will be then be required to assess a number of CAZ options together with proposed measures.

The feasibility study will rely heavily on detailed modelling to project transport trends, associated emissions and subsequent concentrations of NO_2. A specific working group will be assigned formed of council officers, public service health bodies and external consultants. In line with WG's direction, this working group will deliver a Full Business Case for the preferred "FINAL" option scenario.

As discussed previously it is CC's objective to ensure levels are as low as reasonably practicable in the shortest time possible. The production of this CAS & Action Plan provides the basis for the referenced feasibility study in the form of a long list of measures. The document also satisfies CC's LAQM duties by delivering an action plan to improve air quality within its four designated AQMAs. Due to Cardiff's interlinking and converging transport system by addressing the air quality concerns highlighted along the road links outlined by WG it is evident that the air quality concentrations associated with the AQMAs will also be impacted.

As such the measures/actions detailed in Table 7 need to be shortlisted to a number of preferred options which need to be informed by local evidence and understanding. These options will be taken forward for detailed assessment and Cardiff Council will be required to assess these measures and provide robust evidence on the impact of the measures. This will be informed by local traffic and air quality modelling, as this will provide a more detailed assessment of the specific local situation than the national air quality model that currently shows Cardiff to be non-compliant beyond 2020.

8.3 Assessment of Measures

In line with the prescribed Local Air Quality Management Technical Guidance (LAQM TG16), in order to appraise the package of current and proposed mitigation measures for the City of Cardiff, measures which provide the most significant impact on emissions and rank high on a cost benefit analysis should be short listed and subject to further quantifiable analysis.

However, in view of the requirement to demonstrate compliance with the EU Ambient Air Quality Directive, in the shortest time possible, it is felt that the full measures cannot be ranked based on the appraisal format in LAQM TG16. At this stage it is not confirmed what funding resource will be available for the majority of measurements and therefore there is some uncertainty in being able to assess likely implementation dates. What can be confirmed at this stage is that the cited measures will each achieve different levels of air quality impact within different timescales and financial budgets.

With regards to assessing each measure for impact on emissions, as detailed in LAQM TG16 the following guidelines were adopted to quantify the level of impact;

- **Low effect** – action focused on a small proportion of sources contributing to an exceedance;
- **Medium effect** – action focused on only one key emissions source;
- **High effect –** action focused on dealing with key high emitting sources, or a number of emissions sources.

Table 9- Qualitative Assessment Tool for Assessing Actions

Cost		Air Quality Impact		Timescale	
£	**<£100k**	✓	Low	S	6- 12 months
££	**£100k- £500k**	✓✓	Medium	M	1- 2 years
£££	**£500k- £1 million**	✓✓✓	High	L	>2 years
££££	**>£1 million**	-	Negligible	-	

Table 10- Qualitative Assessment of Actions to Deliver Strategic Measures

Strategic Measure	Action	Additional Information	Air Quality Impact	AQMA/ JAQU Identified Areas	Cost	Non- Air Quality Impacts	Implementation Timescale	Funding
Enhance Local Planning Policy	Implementation and consideration of existing Local Development Plan (LDP) policies (KP18 & EN13) during any planning application process.	-	✓	All	-	Section 106 agreements can be used to secure funds for air quality improvement schemes where mitigation is required. Local planning policies to encourage active travel as an alternative mode will contribute to health benefits.	In place	Existing Budgets
Enhance Local Planning Policy	Planning for Health and Well-being SPG	The SPG is supplementary to Policies KP14 and C6 of the adopted LDP.	✓	All	-	-	In Place	Existing Budgets

Table 10- Qualitative Assessment of Actions to Deliver Strategic Measures								
Strategic Measure	Action	Additional Information	Air Quality Impact	AQMA/ JAQU Identified Areas	Cost	Non- Air Quality Impacts	Implementation Timescale	Funding
Enhance Local Planning Policy	Develop Supplementary Planning Guidance (SPG) to provide a specific guidance for air quality in accordance with new developments.	SPG will look at criteria needed to proceed to an AQA/mitigation measures that need to be implemented to ensure any adverse impact is resolved/ additional infrastructure needed to support the uptake of LEVs. The SPG will also look at addressing cumulative impacts derived by planning proposals and look to oppose structures that have the potential to create canyon effect.	✓	All	-	Improved Street Scene	Short (Ongoing)	Existing Budgets

Table 10- Qualitative Assessment of Actions to Deliver Strategic Measures

Strategic Measure	Action	Additional Information	Air Quality Impact	AQMA/ JAQU Identified Areas	Cost	Non- Air Quality Impacts	Implementation Timescale	Funding
	Supplementary Planning Guidance (SPG) "Managing Transport Impacts & Parking Standards"	Published	✓	All	£	Reduced Congestion and enhancements to transport schemes due to income generation improving journey time and quality. Increase in physical activity levels.	In Place	Existing Budgets
	Cardiff's Green Infrastructure SPG	Published	✓	All	£	Increase Green Space and provide a visual enhancement to the area, in particular for townscape and public realm.	In Place	Existing Budgets
Enhance Cardiff's Transportation System	Freight and Delivery Management- Assess and improve where necessary strategic routes for freight timings of planned journeys for in and around City Centre.	-	✓✓✓	All	££££	Increased accessibility via reduced congestion.	Medium	Existing Budgets

Table 10- Qualitative Assessment of Actions to Deliver Strategic Measures

Strategic Measure	Action	Additional Information	Air Quality Impact	AQMA/ JAQU Identified Areas	Cost	Non- Air Quality Impacts	Implementation Timescale	Funding
	Consider establishing a freight quality partnership to provide a forum for discussion with HGV operators.			All			Short	Existing Budgets
	Implement further speed restrictions and enhance those already established "20mph Zones"	CC has introduced 'signs only' 20mph limits in Cathays and Plasnewydd area. Approach coincides with the Safe Routes to School Programme. Such measures are known to have positive impacts to NOx levels- 24%-31% decrease (Jones & Brunt 2017).		All		Safer environment for pedestrians	Short	Existing Budgets
	Cardiff Capital Region Metro	Proposed by WG (Rail and bus based rapid transit routes).		All			Long	City Deal

Table 10- Qualitative Assessment of Actions to Deliver Strategic Measures

Strategic Measure	Action	Additional Information	Air Quality Impact	AQMA/ JAQU Identified Areas	Cost	Non- Air Quality Impacts	Implementation Timescale	Funding
	Development of Cardiff's Central Square Interchange	A part of the proposal is a state of the art Bus Interchange.	✔	All	££££	Increased use of public transport/ reduced congestion/ improvements to accessibility/ improvements to journey time.	Long	WG & Existing Budgets
	Bus Programme- Strategic Bus Network	Improve bus networks and efficiency of the service. Bus lanes have been installed on A470, A4119 & A48. Suggested 400m of bus lane ensures each bus with a time advantage of 5 minutes.	✔✔✔	All	££££	Increased use of public transport/ reduced congestion/ improvements to accessibility/ improvements to journey time.	In Place & Ongoing	WG & Existing Budgets
	Park and Ride programme.	Proposals are in place for a park and ride system at Junction 33 which would look to intercept traffic	✔✔	All	£££	Increased use of public transport/ reduced congestion/ improvements to accessibility.	Medium	S106 Funded and WG

Table 10- Qualitative Assessment of Actions to Deliver Strategic Measures								
Strategic Measure	Action	Additional Information	Air Quality Impact	AQMA/ JAQU Identified Areas	Cost	Non- Air Quality Impacts	Implementation Timescale	Funding
		on the A470, north Cardiff. Park and ride anticipated for Llantrisant Road and expansion of park and ride on A48.						
Increase the uptake of Sustainable and Active Travel	Cycling Superhighways infrastructure. Cardiff's DRAFT Cycling Strategy. Intergrated Network Map (INM).	Cycling Strategy sets out to double number of cycling trips by 2026; 9.2% modal share in 2015 to 18.4% in 2026. Two new cycle superhighways proposed. The INM prioritises cycling and walking routes over 15 year period.	✓✓✓	All	££££	Increase in physical activity and improvements to well-being.	Long	
	Work jointly with bus operators to deliver improvements to the fleet (ULEB and retrofit schemes); prioritise ULEB funded buses on routes impacting AQMAs & outlined routes from the PCM model.	-	✓✓✓	All (City Centre AQMA will see the largest impact based on source apportionment analysis)	££££	Improved health and well-being. Associated noise improvements.	Short	OLEV- 75% funding approved

Table 10- Qualitative Assessment of Actions to Deliver Strategic Measures

Strategic Measure	Action	Additional Information	Air Quality Impact	AQMA/ JAQU Identified Areas	Cost	Non- Air Quality Impacts	Implementation Timescale	Funding
	Schools' Active Travel Plans	Corporate commitment for every school in Cardiff to have an active travel plan by April 2022. CC engagement with 'Living Streets' charity who have developed a 'WOW' (Walk Once a Week) scheme in 7 allocated schools in Cardiff.	✓	All	££	Reduced congestion; enhanced safety; improved fitness & health; raised awareness & behaviour change.	In place/ Ongoing	Existing Budgets & WG Funding (Healthy and Active Fund)
	Car Clubs	-	✓	All	£	Reduced Congestion and improved journey times	Short	Existing Budgets
	Development of the Staff Healthy Travel Charter.	To be launched in April 2019.	✓	All	£	Improved health and well-being. Reduced congestion	Short	Existing Budgets

Table 10- Qualitative Assessment of Actions to Deliver Strategic Measures

Strategic Measure	Action	Additional Information	Air Quality Impact	AQMA/ JAQU Identified Areas	Cost	Non- Air Quality Impacts	Implementation Timescale	Funding
						and improved journey times.		
Implement Renewable Fuels Strategy	Improve and promote the uptake of low emission vehicles by enhancing Cardiff's EV infrastructure and identify opportunities to promote awareness.	Encourage the public and businesses to increase switch to alternative fuels. The Council has been successful in obtaining a bid from the Office of Low Emission Vehicles (OLEV) 36 charge points in 21 locations across the city and accessible to the public by 31st March 2019.	✓✓✓	All	£££		Short-medium	Existing Budgets & OLEV
	Ensure that procurement for Councils fleet considers alternative fuelled vehicles.	Council to fund the hire lease costs of 56 new EVs in 2019/20 (replacing existing petrol/diesel	✓✓	All	££		Short	Existing Budgets

Table 10- Qualitative Assessment of Actions to Deliver Strategic Measures

Strategic Measure	Action	Additional Information	Air Quality Impact	AQMA/ JAQU Identified Areas	Cost	Non- Air Quality Impacts	Implementation Timescale	Funding
		vehicles) and 37 vehicles in 2020/21.						
Public Information and Behaviour Change Initiatives	Promotion and Communication of the benefits surrounding active travel.	Only 25% of Cardiff residents meet physical activity guidelines and 53% are obese or overweight (Welsh Health Survey 2010 and 2011).	-	All	£	Reduced Congestion and improved journey times	Short	Existing Budgets
	Show council support to local air quality awareness campaigns in Cardiff.	Look at various avenues to collaborate with campaigners and other professional bodies.	✓	All	-		Short	Professional bodies/ External investors
	Collaborative working with key stakeholders, such as Public Service Boards (PSBs) & WG	Ensure that any marketing campaigns designed to encourage a modal shift are interconnected with communications	-	All	-		Short	Existing Budgets

Table 10- Qualitative Assessment of Actions to Deliver Strategic Measures

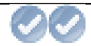
Strategic Measure	Action	Additional Information	Air Quality Impact	AQMA/ JAQU Identified Areas	Cost	Non- Air Quality Impacts	Implementation Timescale	Funding
		teams with PSBs to ensure consistency with marketing themes.						
	Increase public's capabilities to access air quality data via the integration of a smart cities approach.	-	-	All			Short	Existing Budgets/ WG funding
Additional Regulatory Interventions	Improvement of Taxi Licensing Policy - Target older taxi vehicles and look to amend policy guidance	WG considering minimum welsh standard for taxis which could be adopted in Cardiff. Cardiff currently has in place an 'exceptional condition' policy which looks to extend taxi licenses once past an age of 10 years. Currently there are 2,261 hackney carriage/private		All			Short	Existing Budgets & WG funding

Table 10- Qualitative Assessment of Actions to Deliver Strategic Measures

Strategic Measure	Action	Additional Information	Air Quality Impact	AQMA/ JAQU Identified Areas	Cost	Non- Air Quality Impacts	Implementation Timescale	Funding
		hire drivers, 902 hackney carriages and 1,150 private hire vehicles in Cardiff.						
	Enforce vehicle idling charges	Under Road Traffic (Vehicle Emissions) (Fixed Penalty) Regulations 2003, CC has the power to implement “no vehicle idling” areas. CC will need to assess the feasibility and likely benefits of these suggested areas.	✓	All	££		Short	Existing Budgets
	Increase the monitoring capabilities of the council with investment in more real time monitoring.	Two real time monitoring stations on Frederick Street and Richard’s Terrace, Newport Road provides real time data as	-	-	£		Short	Existing Budgets OR Successful bid proposals made to WG for improved Infrastructure

Table 10- Qualitative Assessment of Actions to Deliver Strategic Measures

Strategic Measure	Action	Additional Information	Air Quality Impact	AQMA/ JAQU Identified Areas	Cost	Non- Air Quality Impacts	Implementation Timescale	Funding
		part of AURN network.						
	Encourage/ Facilitate homeworking	Cardiff Council is one of the largest employers in Wales and therefore could look to adopt more flexible/ agile working patterns		All		Quality of life improvements, saved costs on office space, eliminate time lost travelling to office meaning shorter working days, reduced congestion during peak times	Short	Existing Budgets

8.4 Stakeholder Engagement

In order to ensure that Cardiff Council implements a solution that not only delivers compliance in the shortest possible time, but ensures that such a solution is supported and welcomed by citizens, businesses and visitors to Cardiff it will be vitally important to fully engage and work with the public and businesses to ensure that the preferred option implemented meets the citizens expectations.

8.4.1 Consultation on the Green Paper on Transport and Clean Air

At the end of March 2018 the Council launched a Green Paper on Transport and Clean Air[31]. The paper set out a number of proposals/ ambitions termed as 'Big Ideas' on measures to improve transport and air quality in Cardiff. Fundamentally the paper focused on the need to tackle congestion and offer active travel options to discourage unnecessary private car use, keeping the city moving and ensuring the health of citizens. The paper enabled members of the public, businesses and other organisations a chance to score the proposals in terms of preference of them being implemented in Cardiff.
Consultation on the Cardiff's Transport and Clean Air Green Paper was open from the 26th March to the 1st July 2018.
The consultation centred on an electronic survey, with a communication campaign conducted via social media.

The survey received 3,580 total valid survey responses (including 266 partial responses)
The total number of surveys collected from schools was 285. At the time of writing this report the full detailed assessment of the consultation responses is ongoing but some key headline data can be extracted from this survey.

The Top 3 'Big Ideas' were:

- Integrated Ticketing
- Zero Carbon Bus Fleet
- Improving the digital network and user information (for public transport).

The lease favourable 'Big Ideas' were:

- Autonomous Vehicles
- Parking Levies (increase parking charged and or work place parking levies)
- A Total City 20mph Zone

The information above does indicate that there is a desire for an increase use in Public Transport given that the 'top 3' all relate to improvements in public transport measures. Consideration of the outcome of this consultation has informed the refinement of the shortlist of measures.

[31] https://www.cardiff.gov.uk/ENG/resident/Parking-roads-and-travel/transport-and-clean-air-green-paper/Documents/Cardiff%27s%20Transport%20and%20Clean%20Air%20Green%20Paper.pdf

8.5 Shortlist of Local Measures

In line with the Direction received from WG and for the purpose of addressing air quality concerns in the four specified AQMAs the long list of measures derived by Table 10 will be subjected to further appraisal which will reflect the requirements of the HM Treasury Guidance (Green Book), the wellbeing of future generations legislation, and also the Welsh Transport Appraisal Guidance (WelTAG).

The shortlist of measures will be assessed in detail via air quality and transport modelling which will quantify the level of impact to air quality within the designated AQMAs and Defra's modelled road links. As detailed in Section 8.2 this level of detail was outlined in the Initial Plan submitted prior to the 30th September 2018 deadline.

The summarise the long list of measures are;

8.5.1 Enhance Local Planning Policy

M1: Implementation and consideration of existing Local Development Plan (LDP) policies (KP18 & EN13) during any planning application process.

M2: Development of a Supplementary Planning Guidance (SPG) for Planning for Health and Well-being .The SPG is supplementary to Policies KP14 and C6 of the adopted LDP.

M3: Develop Supplementary Planning Guidance (SPG) to provide a specific guidance for air quality in accordance with new developments;

M4: Develop Supplementary Planning Guidance (SPG) "Managing Transport Impacts & Parking Standards; and

M5: Publish Green Infrastructure SPG.

8.5.2 Enhance Cardiff's Transportation System

M6: Freight and Delivery Management- Assess and improve where necessary strategic routes for freight timings of planned journeys for in and around City Centre;

M7: Establishment of a freight quality partnership to provide a forum for discussion with HGV operators;

M8: Implement further speed restrictions and enhance those already established "20mph Zones;

M9: Cardiff Capital Region Metro*;

M10: Development of Cardiff's Central Square Interchange;

M11: Bus Network Programme- Strategic Bus Network to improve bus networks and efficiency of services via increased and improved bus lanes; and

M12: Accelerated Park and Ride programme in NW & NE Cardiff; NW delivery of P&R in north west of Cardiff – J33/ Llantrisant Road – 750 P&R at J33 and 250 P&R off Llantrisant Rd & NE expansion of P & R on the A48.

*** Metro not considered further owing to the fact that Cardiff Council is not able to influence the timescales for implementing this project.**

8.5.3 Increase the Uptake of Sustainable and Active Travel

M13: Development of Cycling Superhighways infrastructure with Integrated Network Map (INM). Minimum of Two cycle superhighways proposed;

M14: Work jointly with bus operators to deliver improvements to the fleet, by securing OLE Buses and priorities such buses on routes impacting AQMAs; and

M15: Development of further School Travel Plans, by continued engagement with 'Living Streets' charity who have developed a 'WOW' (Walk Once a Week) scheme, which is currently undertaken in 7 schools in Cardiff.

M16: Development of Car Clubs in Cardiff, to encourage car sharing schemes.

M17: Promotion and Communication of the benefits surrounding active travel.

8.5.4 Renewable Fuels Strategy and Improve EV/ 0EV Infrastructure

M18: Roll out EV charging locations or identify alternative fuel supplies;

M19: Ensure that procurement for Councils fleet considers alternative fuelled vehicles; and

M20: Through the Public Service Board encourage procurement of alternative fuelled vehicles.

8.5.5 Regulatory Interventions

M21: Improvement of Taxi Licensing Policy, to set minimum vehicle emissions standards;

M22: Implement and Enforce non vehicles idling areas;

M23: Review car parking and car permit charges and allow for reduced rates for EV/OLEV, and increased rates for <Euro 6; and

M24: Increase the monitoring capabilities of the council with investment in more real time monitoring; and

M25: Implementation of a Charging Clean Air Zone.

8.5.6 Public Information and Behaviour Change Initiatives

M26: Increase air quality awareness campaigns in Cardiff, such as Car Free Day;

M27: Collaborative working with key stakeholders, such as Public Service Boards (PSBs) & WG;

M28: Increase public's capabilities to access air quality data via the integration of a smart cities approach; and

M29: Implement a Green Infrastructure/ Living Wall Installation Programme

8.6 Timeline for Delivery of Assessment and Implementation of Preferred Measures

Figure 13 below sets out a time line of the next phases of work that Cardiff will undertake in order to assess the long list of measures to try and demonstrate how we will achieve compliance in the shortest time possible. In addition the timeline shows further dates for which additional work streams will be finalised and implemented. The dates presented are estimated based on our current understanding from Welsh Government.

Figure 13- Proposed Timeline to Develop and Implement Measures to Achieve Compliance for NO_2

Chapter 9 Performance Monitoring and Measurement

In order for the Council to assess whether the overarching aim of the Clean Air Strategy is being or likely to be met the following are the key targets for which we will assess the measurement of the success of this Strategy:

- Achieve all statutory air quality standards in shortest time possible;
- Deliver an ongoing reduction in NO_2 and particulate levels for the duration of this strategy, thus improving air quality beyond statutory requirements;
- Demonstrate a reduction in NO_2 and particulate emissions derived from CC activities;
- Reduce the fraction of mortality attributable to air pollution in Cardiff (and Vale HB);
- Increase the proportion of journeys to work and school made by public transport or active travel methods; and
- Increase in the uptake and use of ultra-low and zero emission vehicles in the City.

PQA

Programme & Project Risk Register

Programme Name: Clean Air Feasibility Study

This log is used to record and track both Programme and project risks. Risks are things that may or may not happen in the future that could have an effect on a Programme or Project's success. This log includes all risks identified over the life of the Programme\Project, including those that have passed and are no longer a threat to the Programme \ Project, those that have been prevented or mitigated, and those that have become issues. Do not delete risk information from this log: it is a permanent record of risks.

Risk Ref No.	Date Entered	Date Last Updated	Measure	Risk Event	Risk Type	Risk Description	Inherent Status			Current Controls	Current Residual Status			Proposed Future Actions	Proximity	Risk Owner	Risk Actioner	Risk Status
							Likelihood Rating (A - D)	Consequence Rating (1 - 4)	Level of Inherent Risk		Likelihood Rating (A - D)	Consequence Rating (1 - 4)	Level of Inherent Risk					
0001	01/03/2019	03/06/2019	Electric Buses	Unable to secure funding for £1.8M shortfall	Financial	ULEB grant allocated 75% cost difference between Diesel Bus and Ebus, and thus there is a shortfall in funding of £1.8M	b	2	Red	Cabinet being asked to consider increase in Commercial Loan to Cardiff Bus to cover shortfall of funidng.	d	1	Amber/Green	Owing to state aid issues Cardiff Bus can only secure funding throguh commercial loan.	< 1 month	CO/CC	JB	Open
0002	01/03/2019	03/06/2019	Electric Buses	Electric substation at Sloper Rd needs upgrade in order to provide sufficient capacity.	Financial	There would be further capital cost to upgrade the substation in order that it could provide suitable capacity	c	1	Red/Amber	Cardiff Bus investigating the capacity of the substation with WPD and the charging requirements with their likely approved supplier.	d	3	Green	Ensure WPD provide suitable assurances or accurate costs for any upgrade requirements.	< 3 months	Bus Operators	JB	Open
0003	01/03/2019	03/06/2019	Electric Buses	Insufficient No. E-Buses available due to market demand	Timescale	EV Bus targets not reached and thus improvements in AQ not Achieved	d	1	Amber/Green	As part of the procurement process Cardiff Bus need to ensure that preferred supplier is able provide sufficient guarantees on supply, discussions on going.	d	3	Green	review procurement documentation	< 12 months	Bus Operators	JB	Open
0004	01/03/2019	03/06/2019	Electric Buses	Replacement Programme Disrupts day to day Cardiff Bus Operations.		Cardiff Buss unable to run certain bus services to schedule, creating disruption for passengers	d	4	Green	Replacement work will be carefully planned to ensure that services continue to operate whilst E-Buses are incorporated into the service.	d	3	Green	review of implementation plan	< 12 months	Bus Operators	JB	Open
0005	01/03/2019	03/06/2019	Electric Buses	Operational problems experienced with New E Buses	Quality	Bus Service Disruption/ Vehicles unable to reach destination/ depot to charge etc.	c	3	Amber/Green	Proposed system will be overnight charging at Sloper Rd, so should ensure that all buses have sufficient charge to operate daily route. However will need to ensure that sufficient testing of all systems is undertaken, and appropriate monitoring/ assessment is undertaken to ensure greatest efficiencies are obtained.	d	3	Green	Appropriate testing of system.	No Time Period	Bus Operators	JB	Open
0006	01/03/2019	03/06/2019	Bus Retrofit	Retrofit project unable to be delivered through approved supplier	Procurement	Supplier unable to meet the order/ demand for retrofit programme	c	3	Amber/Green	Suppliers have previously provided assurances that they can meet demand and have a large manufacturing base. Potential need to identify and assess back-up supplier to ensure that in the unlikely event that approved supplier is unable to deliver.	d	3	Green	ensure demand supply assurances included as part of procurement process	No Time Period	Bus Operators	JB	Open
0007	01/03/2019	03/06/2019	Bus Retrofit	System design is not compatible with the vehicles	Timescale	Technology unable to be installed and thus there could be significant delay in implementing full scheme and thus air quality improvements not met	c	3	Amber/Green	Detailed surveys will be undertaken on the existing fleet requiring retrofit to validate the conditions of the vehicles to ensure that equipment selection is correct. design work or prototyping will be done during the first 6 weeks while waiting for the key components to arrive. On arrival of the parts a "First Off" system will be built and then installed on each of the different vehicle types and tested to ensure that the systems achieve the desired emissions reduction.	d	3	Green	Ensure information is available to supplier of technology and that they account for undertaking surveys as part of Procurement process.	< 12 months	Bus Operators	JB	Open
0008	01/03/2019	03/06/2019	Bus Retrofit	Variations in equipment costs due to the volatile European currency market could lead to an increase in the cost of the project	Financial	Cost overrun on project	c	3	Amber/Green	Fixed price for the equipment to be agreed across the entire manufacturing schedule, prior to any grant funding being released.	d	3	Green	Ensure prices are fixed as part of procurement process.	< 12 months	Bus Operators	job	Open
0009	01/03/2019	03/06/2019	Bus Retrofit	Retrofit Programme significantly disrupts Bus services in Cardiff	Resource	Bus Operators unable to run bus services to schedule, creating disruption for passengers	c	3	Amber/Green	Retrofit work will be carefully planned to take place overnight or at weekends when demand and scheduling allows for a reduction in the peak vehicle requirement (pvr) to occur without disrupting services for passengers.	d	3	Green	Ensure fitting programme agreed with operators	< 12 months	Bus Operators	JB	Open
0010	01/03/2019	03/06/2019	Bus Retrofit	Retrofit technology fails	Quality	NOX emissions are not in line with expected performance and NO2 concentrations are not reduced in an effective manner as a result.	c	4	Green	Green Urban Technologies have demonstrated significant NOx reductions, greater than 95% by the installation of their Selective Catalytic Reduction Technology (SCRT). The system was independently tested over the Millbrook London Bus Test cycle (MLTB).	d	3	Green	Ensure approved supplier have up to date testing results to demonstrate effectiveness of technology, which must be demonsrated as part of operators applications for funding.	< 12 months	Bus Operators	JB	Open
0011	01/03/2019	03/06/2019	Taxi Measures	Revised Policy does not get approved by Public Protection Committee	Legal	failure to require minimum emission standards on all new grants and new vehicles.	c	1	Red/Amber	Ensure that the report to Committee clearly sets out the reasoning for requiring the policy changes, and that it is directly linked to the Legal Direction.	C	3	Amber/Green	Development of mitigation scheme to ease burden on drivers/ taxi trade	No Time Period	SRS	JB	open

Risk Ref No.	Date Entered	Date Last Updated	Measure	Risk Event	Risk Type	Risk Description	Likelihood Rating (A - D)	Consequence Rating (1 - 4)	Level of Inherent Risk	Current Controls	Likelihood Rating (A - D)	Consequence Rating (1 - 4)	Level of Inherent Risk	Proposed Future Actions	Proximity	Risk Owner	Risk Actioner	Risk Status
0012	01/03/2019	03/06/2019	Taxi Measures	Appeal/ JR by Taxi Trade on changes to policy	Legal	Opposition could delay the implementation of the revised policy which will fail to see the turnover in taxi fleet to Euro 6 or ULEVs	**b**	**2**	Red	Ensure that sufficient engagement with the industry continues to take place to educate the industry on the justification of the proposals in terms of the AQ Direction. Engage with Welsh Government to establish suitable Grant Funding Scheme to assist taxi drivers/ operators to upgrade vehicles.	**c**	**3**	Amber/Green	Development of mitigation scheme to ease burden on drivers/ taxi trade	No Time Period	JB	JB	Open
0013	01/03/2019	03/06/2019		Increase in cross boarder taxis operating in Cardiff	Quality	Cardiff unable to prevent older taxis, that are licensed in neighbouring authorities who may not apply emission standards as part of licensing requirements, and such taxis can operate in Cardiff.	**a**	**3**	Red/Amber	Need to work with neighbouring authorities to promote uptake of similar policies. For Vale and Bridgend this should be straightforward as licensing undertaken by SRS. Caerphilly and Newport also face challenging AQ issues so should also be desire within these Councils to follow suit if they have not already done so.	**c**	**3**	Amber/Green	Work collaboratively with Welsh Government on ongoing consultation for them to implement national emissions standards for taxis in order to reduce burden on taxi trade in Cardiff in terms of achieving emission standards.		SRS	JB	Open
0014	01/03/2019	03/06/2019	City Centre Schemes	Impact on Wider Network	Quality	**Impact on Wider Network:** There is a risk that displaced traffic could have a negative effect on the wider traffic network	**b**	**2**	Red	Full ANPR, MTC and ATC survey to be conducted on project area and the surrounding network area. This data will be used to create wider network model where options will be retested. An impact assessment on the wider network will be carried out as part of this work and will	**c**	**4**	Green	Conduct Survey Expand Transport Model Create Reports	< 12 months	GS	JB	Open
0015	01/03/2019	03/06/2019	City Centre Schemes	**Impact on Local Businesses and Residents:**	Communication	Local businesses could reject the scheme based on the changes to their operations	**c**	**2**	Red/Amber	Private engagement with key stakeholders will be used to help inform the scheme design. An operational plan detailing how residents, businesses, buses, taxis and key stakeholders will use the new transport layout will be created.	**c**	**4**	Green	Review feedback from consultation to revised designs as necessary	< 12 months	GS	JB	Open
0016	01/03/2019	03/06/2019	City Centre Schemes	Objections to the schemes	Communication	Changes of this scale can cause worry among the public, there is a risk the scheme will not gain public support	**c**	**1**	Red/Amber	A full consultation plan will be implemented as part of the pre construction phase. Plans will be submitted online and will be accompanied by a consultation pack. Drop in sessions will also be organised for members of the public and businesses on street.	**c**	**4**	Green	Review feedback from consultation to revised designs as necessary	< 12 months	GS	JB	Open
0017	01/03/2019	03/06/2019	City Centre Schemes	Air Quality Impacts	Legal	There is a risk that the current scheme will not achieve the required air quality improvement	**d**	**3**	Green	The Transport Team will work with their own Traffic Modelling Consultants and the Council's Air Quality Team and associated Consultants to ensure that the necessary air quality impact is achieved as part of the scheme. The current designs will be modelled on an Air Quality model and fed into the current modelling work carried out by RICARDO and Mott MacDonald.	**d**	**4**	Green	Review of results from local modelling with modelling work undertaken as part of the feasibility study, and include results of local modelling in FBC as necessary.	< 3 months	JB	JB	Open
0018	01/03/2019	03/06/2019	City Centre Schemes	Historical Environment Around Cardiff Castle	Legal	Cadw requirements: Due to listed structures in and around the Castle area. There is a risk to the design altering fundamentally, having a detrimental effect on the bus network.	**d**	**3**	Green	Meeting with conservation planning officer to discuss Cadw requirements	**d**	**4**	Green	Ensure advice from conservation officer is sufficient and meets any requirements of CADW.	< 12 months	GS	JB	Open
0019	01/03/2019	03/06/2019	City Centre Schemes	Presence of heavily contaminated soils/ materials	Financial	Potential risk of existing material under current carriageway and footway could be contaminated. Additional cost could be associated with excavation and disposal	**c**	**1**	Red/Amber	Undertake site investigation sampling to establish the current makeup of the carriageway to assess disposal costs.	**d**	**4**	Green	investigation will enable robust assessment on contamination to allow appropriate disposal/ reuse options to be developed.	< 12 months	GS	JB	Open
0020	01/03/2019	03/06/2019	City Centre Schemes	Ground Conditions:	Financial	West Gate Street has poor existing ground conditions, with this in mind there is a potential risk that the existing ground conditions for Castle Street and Wood Street could be in a poor state and additional carriageway make up may be required	**c**	**2**	Red/Amber	Undertake site investigation sampling to assess the current makeup of the carriageway to assess any additional costs	**d**	**3**	Green	investigation will enable robust assessment of material to enable accurate assessment of any additional make up costs.	< 12 months	GS	JB	Open
0021	01/03/2019	03/06/2019	City Centre Schemes	Statutory Undertakers/ Supplies	Health & Safety	Due to the location of the site, there is a high volume of statutory undertakers equipment present in the footways and carriageway. Potential risk of the proposal clashing with existing services causing possible diversions	**c**	**2**	Red/Amber	A radar survey has been undertaken for Wood Street, and a radar survey has been commissioned for Castle Street. Check the proposal against the radar survey to reduce possible conflicts	**d**	**2**	Amber/Green	Review results of radar services and ensure detailed and accurate service plans available	< 6 months	GS	JB	Open
0022	01/03/2019	03/06/2019	City Centre Schemes	Impact of Construction on Surrounding stakeholders	Communication	Due to the number of surrounding stakeholders i.e. Principality Stadium, Cardiff Castle, Carparks. Access will be required to be maintained throughout the construction period to limit any financial losses on the stakeholders	**d**	**3**	Green	Contractor to supply a detailed Construction Phase plan for undertaking the works. Contractor to attend stakeholder meetings to understand stakeholders requirements	**d**	**2**	Amber/Green	Agreement of Construction Phase Plane	No Time Period	Contractor	GS/JB	Open
0023	01/03/2019	03/06/2019	City Centre Schemes	Impact of Construction on Existing and Future Developments	Quality	A number of developments are due to be in construction or starting construction during the construction phase. Potential conflict between the Principal Contractor and development Contractor	**d**	**1**	Amber/Green	Project Manager to obtain any details of future development, or current developments and pass on to the contractor to enable them to liaise with.	**d**	**4**	Green	Contractor to undertake appropriate liaison during works,	No Time Period	Contractor	GS/JB	open
0024	01/03/2019	03/06/2019	City Centre Schemes	**Impacts to Highway Network.**	Timescale	Due to the location of the scheme it is vital that the highway network remains unrestricted during peak times of the day	**d**	**4**	Green	The working restrictions will be set out in the contract, the contractor will have to work within the set working restrictions	**d**	**4**	Green	ensure contractor works to required restrictions.	No Time Period	GS	JB	open
0025	01/03/2019	03/06/2019	General Issues	Government led variation	Timescale	Legislative - a change in the underlying requirements from Government - this could be led by additional court cases brought by environmental pressure groups resulting in more stringent AQ targets	**d**	**3**	Green	Continue with regular bi monthly meetings with WG to ensure that any such issues are informed at the earliest stage. Ensure adequate financial contingency is available.	**d**	**4**	Green	Meetings scheduled up to and beyond end of June	< 12 months	JB	JB	open

Risk Ref No.	Date Entered	Date Last Updated	Measure	Risk Event	Risk Type	Risk Description	Likelihood Rating (A - D)	Consequence Rating (1 - 4)	Level of Inherent Risk	Current Controls	Likelihood Rating (A - D)	Consequence Rating (1 - 4)	Level of Inherent Risk	Proposed Future Actions	Proximity	Risk Owner	Risk Actioner	Risk Status
0026	01/03/2019	03/06/2019	General Issues	Failure to communicate the benefits and impacts of the plan following its introduction	Communication	Insufficient resources to deliver effective communication campaign	**d**	**2**	Amber/Green	Comprehensive communications strategy has been developed to ensure appropriate engagement with key stakeholders including local businesses, the public and the media. Comms team have been engaged to develop and deliver strategy	**d**	**4**	Green	Develop further commiunicatins strategy for Implementation Phase, plus statutory consultation of City Centre Schemes	< 1 month	ILD	JB	open
0027	01/03/2019	03/06/2019	General Issues	Cardiff Council is at risk of objections of the preferred option which could delay the production of the FBC	Legal	NO2 reductions not achieved, the Council is at risk of fines and other legal challenges related to failure to comply with the AQ directive, and failure to deliver Final Plan by 30th June	**c**	**2**	Red/Amber	A stakeholder engagement exercise has been developed to inform key stakeholders such as bus companies, taxi forum, cycling groups and the wider public in general.	**d**	**3**	Green	Feedback from consultation will be used to inform/ refine the preferred option in the FBC.	< 3 months	ILD/JB	JB	Open
0028	01/03/2019	03/06/2019	General Issues	Loss of critical staff resource	Resource	Loss of momentum on delivering Final Plan	**d**	**4**	Green	Delivery of Air Quality Plan is a high priority for the Council, and resource will be made available should key current staff no longer be available.	**d**	**4**	Green	Review project resources as necessary	< 6 months	AG	JB	Open
0029	01/03/2019	03/06/2019	General Issues	FBC/ preferred option rejected by Welsh Government.	Financial	Failure to agree preferred option and obtain sufficient funding to implement.	**d**	**2**	Amber/Green	Close Collaboration between Cardiff Council and Air Quality Branch at WG has helped to identify such risks. Feedback from Welsh Government has been instrumental in CC developing the OBC	**d**	**3**	Green	Continued dialogue and collaboration with Air Quality Branch and Minster at WG>	< 6 months	JB	JB	Open
0030	29/05/219	03/06/2019	General Issues	**FBC challanged by Client Eartt or Other body**		Plan is challenged and faulure to commence implementation of preferred option to reduce exposure and implement plan to achieve compliance	**c**	**3**	Amber/Green	Process has ensured that the requirements of the legal tests have been addresssed in report. Client Earth inlcuded in stakeholder engangement and their views consider in feedback from Healthy Air Cymru	**d**	**3**	Green	Continued dialogue with key stakeholders including Client Earth to engage on Final Plan. Furhter statutory consultation on City Centre Schemes.	< 1 month	JB		Open
									#N/A				#N/A					

UCHELGAIS PRIFDDINAS

CAPITAL AMBITION

Clean Air Consultation

Report
May 2019

Gweithio dros Gaerdydd, gweithio gyda'n gilydd
Working for Cardiff, working together

#gweithiogydangilydd
#workingtogether

CARDIFF
CAERDYDD

CARDIFF RESEARCH CENTRE

Clean Air Consultation

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Background

There is no doubt that air pollution is damaging to the human health and the environment.

Public Health Wales have stated that poor air quality is probably the second greatest health concern after smoking and is the most significant environmental determinant of health.

Recent work by Public Health Wales estimates that the equivalent of over 220 deaths each year among people aged 30 and over, in the Cardiff and Vale Health Board area, can be attributed to Nitrogen dioxide (NO_2) pollution with many more citizens suffering ill health as a consequence of poor air quality.

The Council has been undertaking a detailed study into air quality as a result of a legal requirement which has been placed on the Welsh Government, which requires the Council to take action to reduce pollution levels (NO_2) to the legal limit which is set out in European legislation in the shortest possible time.

What are the Results to Date?

Detailed air quality and transport modelling has taken place across the city to forecast NO2 levels and the results have identified one street where EU legal limits are likely to be breached in future years. The results have showed that only Castle Street, which runs in front of the Castle by Westgate Street to Duke Street, is likely to fail legal compliance beyond 2021 if nothing is done to reduce traffic pollution.

Although the modelled data, which is required under the EU Directive, has only indicated that Castle Street will be in breach of the required level, the Council also has a number of Air Quality Management Areas (AQMA) across the City, where pollution levels also remain a concern.

What are the Solutions?

The most recent Outline Business Case has concluded that a package of non-charging measures is the preferred option when compared with a charging Clean Air Zone.

The main reason for this is that that the non-charging measures deliver wider air quality benefits across all of Cardiff when compared directly to the results of the charging Clean Air Zones.

Further government guidance is clear that where pollution limits can be met by non-charging solutions that these should be the preferred option over any charging scheme.

The proposed measures are currently concept designs at this stage and look to tackle the problem of air pollution in the city centre. An outline bid for funding has been made to the Welsh Government for the following schemes and these will be refined, following public consultation and cabinet approval as we develop the full business case:

- Implementation of electric buses to replace the oldest and most polluting buses – costing £1.8m
- Introduction of a Bus Retrofitting Scheme for bus operators in Cardiff to upgrade older buses so they meet Euro VI engine emission standards – costing £1.4m
- Major changes to both Castle Street and Westgate Street and the city centre loop to allow for better and more efficient movement of public transport (buses) and increasing active travel capacity in the City Centre – costing £18.9m
- Review and implement a revised taxi policy to ensure that all applications to grant a 'new vehicle license' or for a 'change of a vehicle on a current license' are only approved for vehicles that meet the latest Euro 6 emission standards – costing £5.5m.
- Improvements to Active Travel and increased 20 mph areas – costing £4.5m View questions and answers on the clean air project.

Research Methodology

An online survey was developed, which could be only accessed from a page on the Council website providing the background information on the proposals. Links to the webpage were distributed to members of the Council's Citizens' Panel, consisting of over 5,000 residents across the city, and a list of key stakeholders, listed in Appendix 1. In addition, 3,000 letters promoting the consultation and engagement events were distributed to residents and businesses in the city centre.

Public engagement events were also held, giving members of the public an opportunity to ask further details about the scheme from members of the Project team:

April 13th: Angel Hotel (Prince of Wales Suite – Ground floor)
April 20th: Central Library (level 3)
May 4th: Angel Hotel (Rhymney Suite – Floor 1)
May 11th: Central Library (level 3)

Both the survey and the engagement events were also promoted through local news media, and via the Council's social media channels – 52 posts were released throughout the consultation period, reaching 1.9 million users, and generating 2.1 thousand clicks.

After data cleansing to remove any blank or duplicate responses, a total of 1,303 responses were received for the consultation; 76 members of the public attended the Engagement Events.

Open-ended responses received from stakeholders note the organisation where this was identified. Any responses in this report attributed to Healthy Air Cymru were received from Sustrans Cymru on behalf of HAC, and are a joint response from its members - British Lung

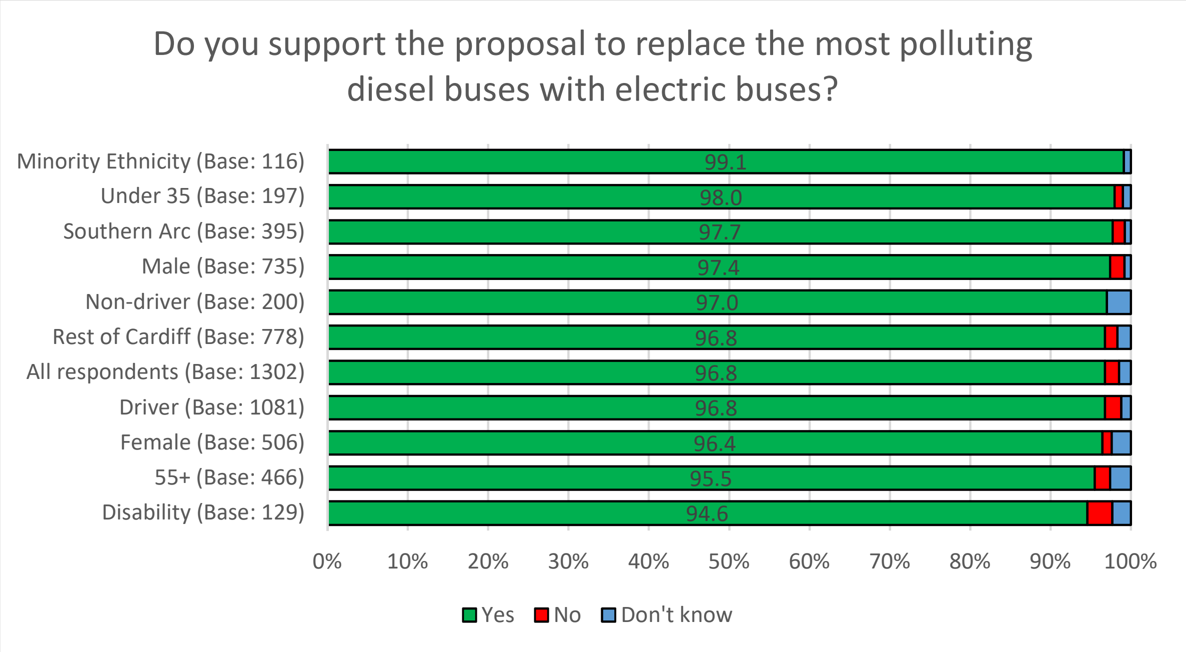
Foundation, British Heart Foundation, Client Earth, Living Streets, Royal College of Physicians Wales, Sustrans Cymru and Swansea University) and are denoted with * .

Research Findings

Buses

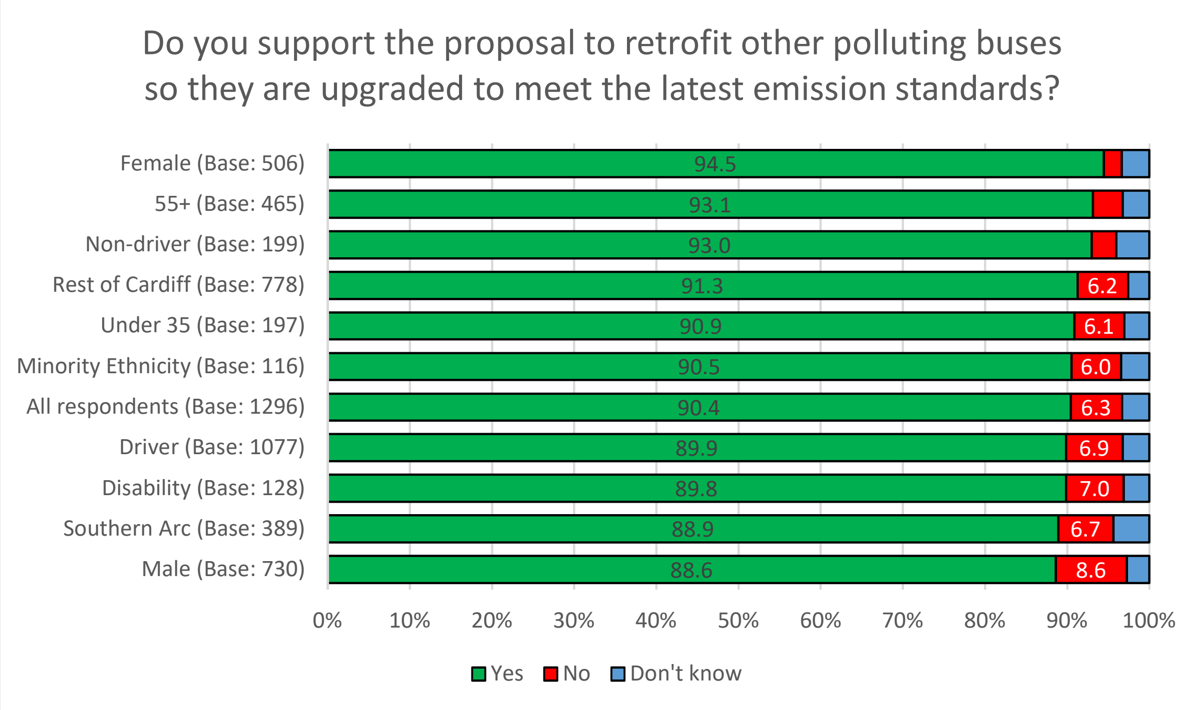
1 Do you support the proposal to replace the most polluting diesel buses with electric buses?

Support for the proposal to replace the most polluting buses was overwhelming, with 96.8% of all respondents in agreement; the lowest level of support stood at 94.6%, amongst respondents identifying as disabled.



2 Do you support the proposal to retrofit other polluting buses so they are upgraded to meet the latest emission standards?

There was also strong support to retrofit other polluting buses, at 90.4% overall.



3 Do you have any other comments regarding the introduction of cleaner buses in Cardiff?

A total of 496 comments were received for this question, which have been grouped into themes. The top three are shown below; a full list of themes can be found in Appendix 2.

Theme	No.	%	Example Comments
Support the proposal	99	*20.0*	*An excellent idea. I use the bus regularly and wholeheartedly support this plan.* *I think this would be a quick easy win and fully support it* *Wholly in support, regardless of cost* *Do it all over the city, not just the city centre. How wonderful would it be if we had a bus station that could charge buses as they waited for passengers?* *Way to go.* *I'm very supportive of measures to update public transport provision and reduce pollution and am glad to see it prioritised.*

All buses to be electric/ULE/green	94	*19.0*	*36 electric buses is not enough. We need at least 90% of buses to be electric and the other 10% to meet the lowest emission standards.* *What is the point of upgrading buses to cleaner diesel when the aim should be electric? Cardiff Bus bought diesel as a cheaper option to electric, Cardiff Council is not providing enough charging points so this smacks as a short term saving to gloss over a short sighted investment plan.* *All buses and Council vehicles should be replaced by less polluting electric vehicles.* *All of the buses should be electric. I cough in the mornings at different times of the year from the bus exhaust and pollution I breathe in while riding in the city centre.* *100% of buses in Cardiff should be electric, including coaches and stagecoach services not just Cardiff Bus*
Other issues with buses - Reliability, cleanliness, Demand, Dedicated Bus station, Accessibility	83	*16.7*	*The bus routes need to be looked at. As they are incredibly long for no reason - a journey on the bus in Cardiff will take around the same time if you are walking to your destination. The busses in Cardiff are a time wasters and unreliable in term of time and even showing up at all sometimes as I lived in other cities and that was not the case. So no matter what kind of bus it is me as a professional and have no time to waste I will not trust Cardiff buses to commute. I did not feel the need to get a car till I moved to Cardiff unfortunately. Due to the disappointing service.* *get rid of bendy buses as they snarl up the traffic by blocking the road* *Buses are the worst pollutants in Cardiff currently, really discouraging me to cycle, I end up stopping and coughing so many times I get stuck behind one. Also, they are terribly managed, extremely unreliable and polluting while carrying 2 or 3 passengers* *This is only good if you stop cutting bus routes, buses run on time, and they stop being cancelled.* *I am disappointed the bus station at Central Square is still incomplete. It sends out the wrong message about a commitment to public transport.*

A number of comments responses were received from Stakeholders and organisations in response to this question:

Healthy Air Cymru *

Air pollution is killing tens of thousands of people prematurely across the UK every year. Both particulate matter (PM10 and PM 2.5) and Nitrogen Dioxide (NO2 a part of Nitrogen Oxide [NOx]) have detrimental effects on our health. Road transport is responsible for 80% of NOx pollution where legal limits are being broken. But it's not just burning fuel that causes the problem.

In London, where there is good data, 45% of the particulate matter comes from tyre and brake wear – so even if we switched all the vehicles to electric, we'd still have a damaging amount of very fine dust as a result of all the traffic. In Wales, PM2.5 pollution contributes to more than 13,500 associated life-years lost.

It is great to see that Cardiff Council are planning to reduce the emissions coming out of their bus fleet, electrification will have an impact on reducing NOx in our city centre, but may contribute higher levels of particulate matter. Sustrans Cymru understand that the air quality targets set for Cardiff do not mention particulate matter, but that should not remove Cardiff's duty to consider air quality more broadly.

The biggest contributor to NOx levels in Cardiff are cars, yet Cardiff are not proposing any measures directly on cars. Modal shift from motorised transport to cycling and walking can have a positive effect on air quality as well as reducing congestion and improving public health through increased physical activity. Sustrans Cymru are pleased with the proposals that Cardiff council are recommending to reduce illegal limits of air pollution in the city centre. The investment in progressive walking and cycling infrastructure is something we have been calling for, and we believe that when these plans are linked up to the walking and cycling developments that are taking place city wide, Cardiff will see a change in the way in which people move around. However, we would like to see Cardiff taking bolder action to encourage people to leave their cars behind. See our response to question 9.

Unison Cardiff Central Young People's Officer

Yes, the city centre should be made a car free zone. Only public transport should be allowed and loads of cycling lanes. Reintroduce the trams and make all public transport free and publicly owned. If Cardiff bus was nationalized this would insentience people not to drive and to take public transport, making the city healthier, cleaner, improving quality of life and would make the city far more attractive to tourists.

Academia (Unspecified)

The elephant in the room here is the lack of bus station, & moreover one big enough to accommodate all bus services. Until that is in place, people are seriously put off using buses. A functional bus station is needed - like, or even better than, the one that was demolished yonks back - in order that people can wait in the dry w/o draughts, can easily see which buses go from where & when, and can access was, etc. while waiting

Professional Driver

Diesel engines can be fitted with a type of catless that would bring down CO2. Instead of spending fast amount of money why not try the cheapest version first.

Professional Driver
Remove all speed humps which are according to the World Health Authority a major cause of localised pollution.

Professional Driver
What batteries will be used in electric buses? Are the batteries produced efficiently and without causing harm to the environment?

Professional Driver
Should have been done a long time ago!

Professional Driver
Reduce the number of theses to reduce pollution due to not being used, running empty.

Professional Driver
Council tax payers should not have to contribute, higher fares should pay these changes along with Welsh assembly funding

Professional Driver
The latest diesel engines using ADD BLUE are very clean and I feel this could be a more cost effective solution.

Professional Driver
What is wrong with trams and trolley buses?

Professional Driver
Although a higher cost, replacing buses with Electric Vehicles should surely be more beneficial in the long run? Further reduced Emissions, potential running costs compared to newer vs older vehicles; including the complexity of a combustion engine compared to EV?

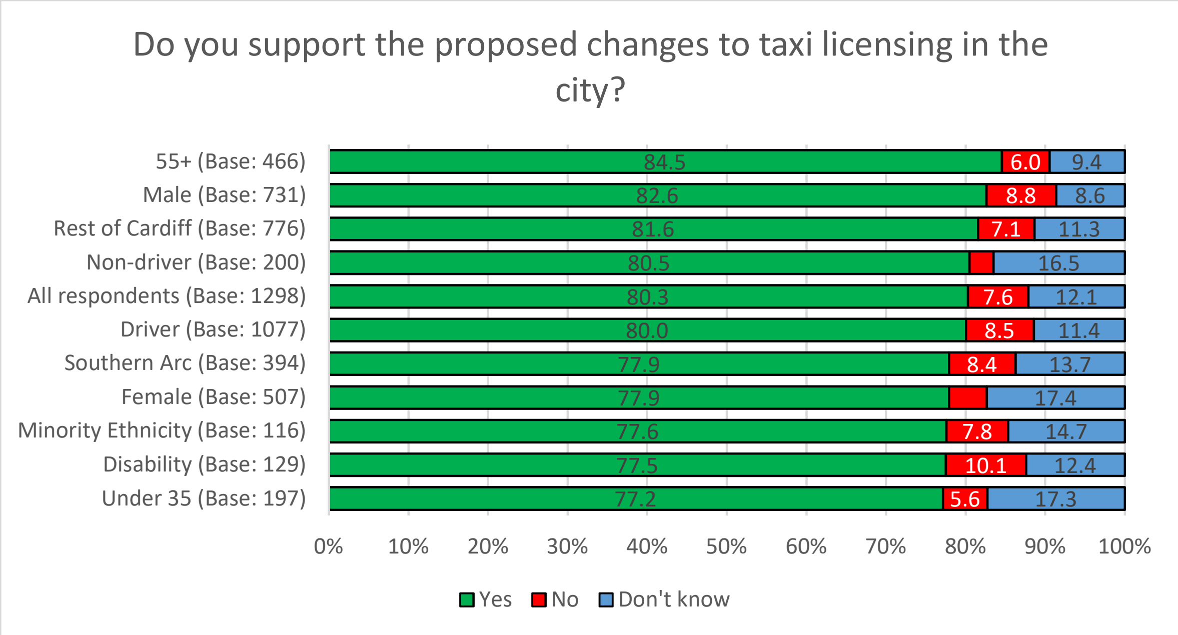
Taxis

4 Do you support the proposed changes to taxi licensing in the city?

The following changes to taxi licensing were put forward:

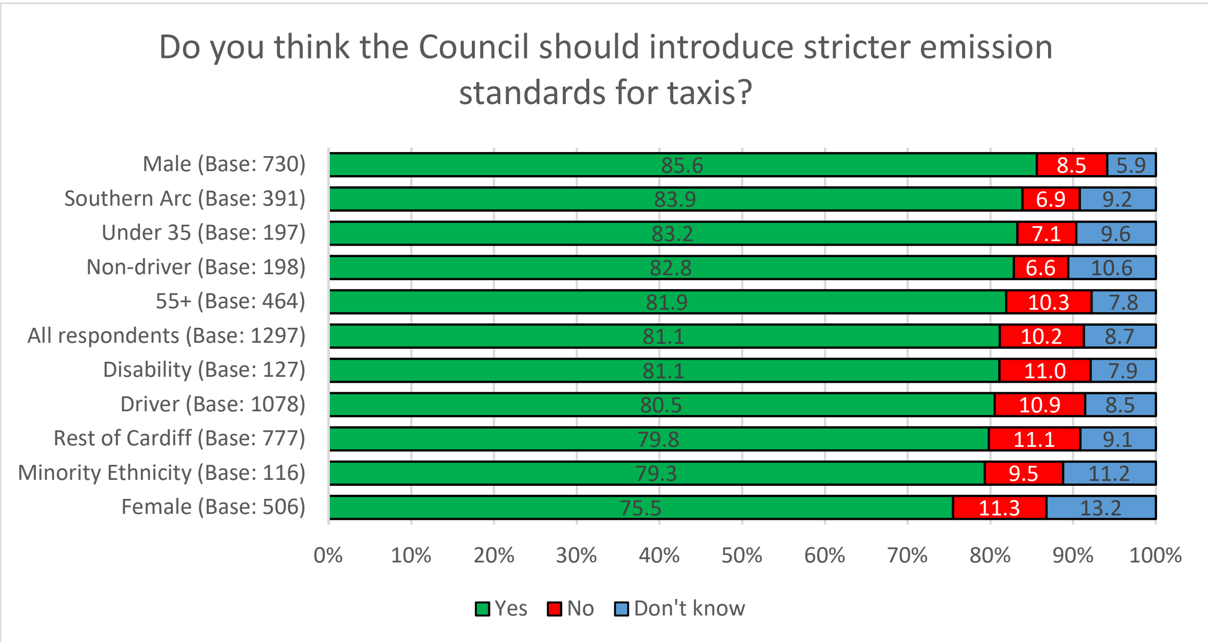
	Current Policy			**Proposed Policy**
Specification	**Saloon/ Multi-Purpose Vehicles**	**Prestige vehicle**	**Purpose Built Hackney Carriage**	**All licensed vehicles**
Maximum age at first application	25 months	Under 10 years	Under 10 years	Under 5 years old **and** meet or exceed Euro 6 standard
Maximum licensable age (unless vehicle complies with exceptional condition policy)	6 years	10 years	10 years	10 years old
Age at which vehicle may be annually tested/ 12 month license issued	Under 4 years	Under 4 years	Under 10 years	Under 5 years old
Age at which vehicle is tested 6 monthly/6 month license issued	4 years	4 years	10 years	5 years or over

Four in five respondents (80.3%) supported the proposed changes to taxi licensing:



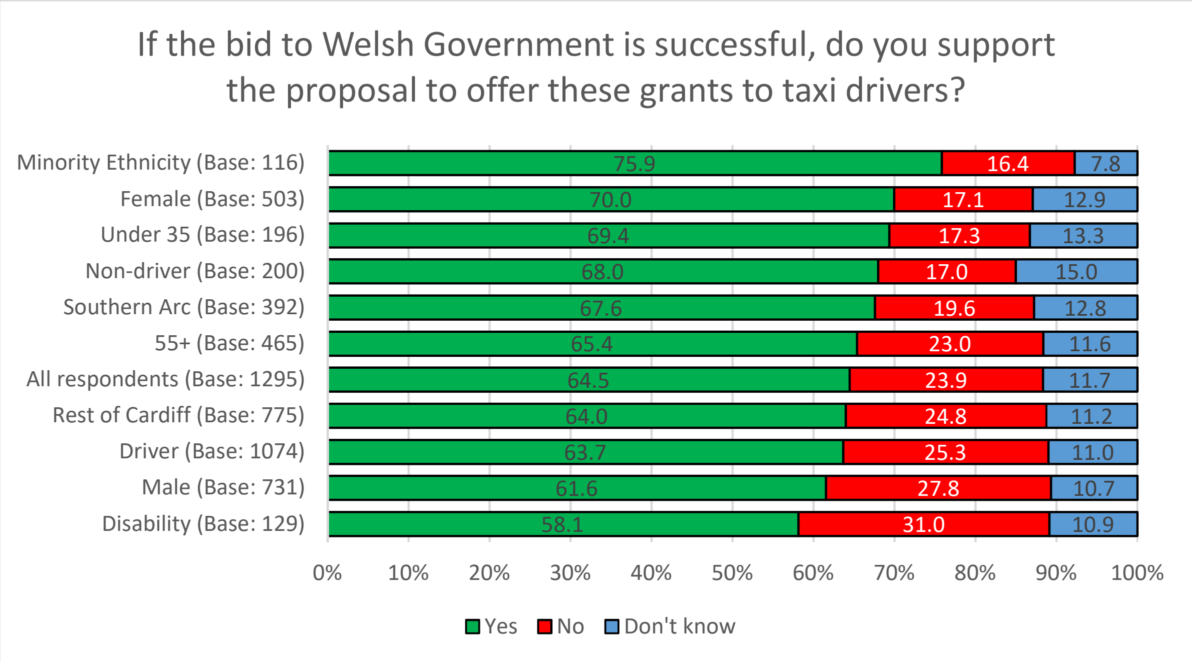
5 Do you think the Council should introduce stricter emission standards for taxis, for example only allowing new licences or renewals to be granted for ultra-low emission vehicles only (i.e., fully electric or hybrid etc.)?

At least three quarters of each of the demographic groups analysed supported the introduction of stricter emission standards, with 75.5% of females, 85.6% of males, and 81.1% of all respondents supporting this proposal.



6 The Council is seeking financial assistance from the Welsh Government to offer grants to taxi drivers for upgrading their vehicles to meet the new standards. If this bid is successful, do you support the proposal to offer these grants to taxi drivers?

The consensus of opinion shown for other proposals was less apparent regarding the offer of grants to taxi drivers to upgrade their vehicles to meet the new, stricter, emission standards. Support ranged from 58.1% of respondents identifying as disabled, through 64.5% of all respondents, to 75.9% of respondents from a minority ethnicity.



7 Do you have any further comments or suggestions on how to change taxi licensing rules to improve air quality in the city?

A total of 442 comments were received for this question, which have been grouped into themes. The top three are shown below; a full list of themes can be found in Appendix 4.

Theme	No.	%	Example Comments
All taxis should be Low Emission	86	19.5	*Has to be all electric* *We need to go full electric / hydrogen on all taxis in Cardiff by 2025, and support rapid development of renewable energy sources of electricity / hydrogen.* *Complement stricter emission standards with incentives to upgrade vehicles to electric ones.* *Not to issue new licences unless hybrid or fully electric after 2021* *All taxis should be electric or hybrid.*
Taxi firms/ drivers should pay	68	*15.4*	*Taxis are the responsibility of the operator - public money should not be spent to pay for their cleaner vehicles.* *I would have concerns that public money is paying for someone who privately owns a vehicle, to get a newer vehicle, which they could sell at some point and keep the full amount of money. Should they have a caveat that if they cease operating within 5yrs of the grant, they repay the grant, otherwise they could receive the grant, retire within a month, and keep the car/grant. I would love money to be given to me to replace my diesel car! What about self-employed people i.e. builders, who travel the whole city. They are providing a service to the public too, the same as taxi drivers - it's all private work, to earn a living. It's discriminatory if only taxi drivers are helped.* *Taxi drivers will not need grants - if cars are disincentivised from the city centre (with taxis exempt) then their revenue will be higher* *Subsidy is inappropriate otherwise everyone should get it*
Discourage idling	61	*13.8*	*Taxis (and buses) often sit empty with their engines running. This should not be allowed and measures should be put in place to discourage this practice* *Prohibit and enforce measures to prevent idling engines whilst taxis are waiting.* *A rule that states that taxis engines must be switched off when they are not driving. You see entire ranks of them all with their engines on whilst waiting for customers just because they want the radio on.* *Ban buses and taxis from being allowed to idle their engines at stops of any kind*

A number of comments responses were received from Stakeholders and organisations in response to this question:

Unspecified Organisation
Cardiff has too many taxis as it is. Most are dangerously old. No public money should go to upgrading cars. They should all have to be green or license revoked. Maybe green taxis pay lower fees? Also, can we have city colour scheme? Tourists find it hard to spot taxis. The ones that are black with white bonnets look stupid - one tourist told me they look "stolen"

Unison Cardiff Central Young People's Officer
Yes, lower the amount of taxis also create penalties for taxis which are parked and have their engines running.

Academia - RTPI member
Taxis are still cars on the road the money would be better spent on newer buses or extra train carriages or safer cycling and walking routes - walking buses for schools, 20mph through residential areas, better play areas within walking distance of homes.

Cardiff University
If there is inadequate financial support for taxi owners to change, we are likely to see a reduction in taxis and the a rise in price, which in turn will encourage people to bring their private cars more into the city centre, especially for pickups from bus or train stations

Cardiff University
Taxis as a whole should be discouraged. Even hybrids contribute to public health issues through brake dust etc, and contribute to congestion which makes pollution from other vehicles much worse. Taxis should be discouraged in favour of public transport (although, for this to be viable public transport would have to be improved).

Environmental health lecturer
Better use of taxi ranks so ensure they are located in appropriate places/spaces

Cardiff University
The government should be working for buses. If taxi drivers want to get a hybrid system, they should finance this change by themselves.

Castle Court Residents Association
There should be much, much tighter control over the licensing rules to eliminate rogue taxi drivers

Professional Driver
Why should Taxi have help from the Welsh Office when the car owner have to take the full plenty of the cost with no government help? I do not pay council tax to subsidize taxi services

Professional Driver
Remove all speed humps.

Professional Driver
Taxi drivers are a business. What other businesses, i.e. delivery vans, driving schools would be offered a grant? The very latest diesel cars are very clean. How clean really are fully electric, taking into account the mining of lithium. Please don't make a knee jerk decision which will harm the environment.

Professional Driver
This should have been done a long time ago. Scottish government offer a £50k interest free loan to everyone to upgrade to hybrid/EV. Why are we so far behind? It doesn't have to be £50k, you can buy a good hybrid for less than £30k

Professional Driver
Why should the public pay for this? And why are the council spending more money on Cardiff Bus? Electric buses are NOT greener.

Professional Driver
There are too many taxis in Cardiff getting rid of the oldest would be a good start.

Professional Driver
If you are going for a grant for Taxi's why not HGV's LGV's and personal cars.

Professional Driver
If funds would allow, at least all Hackney Carriage Taxis operating in the City should be Hybrid vehicles at least, with Private Hire having go adhere to Strict Emissions tests.

City Centre Schemes

To achieve the goals set out this plan, additional road space has to be given to both public transport and active travel in the city centre. By improving the infrastructure, sustainable travel will become a quicker and more attractive option.

At this stage of the process, the designs being put forward only show the concept of what we are trying to deliver. All of these projects will be subject to a competitive tender exercise, so there are no detailed designs at this stage. The images below show the council's intentions in terms of the road design layout. Detailed consultation will take place on each project, when the detailed designs are available.

City Centre West

The main aim of this scheme is to accommodate the new Transport Interchange and Central Square Development, whilst also Improving Air Quality within the City Centre Air Quality Management Area. This could be achieved by removing through-traffic from Westgate Street and installing a new highway layout that will improve and connect the current bus network with the new Interchange, Central Square, Central Station and the City Centre Enterprise Zone. In addition, the scheme could offer improved safety for pedestrians via improved pedestrian crossing facilities, 20mph speed limits and an improvement to the pedestrian environment outside of the national stadium. The scheme could also install a network of stepped cycle tracks to connect the area with the proposed cycleway on Castle Street and the Taff Trail routes.

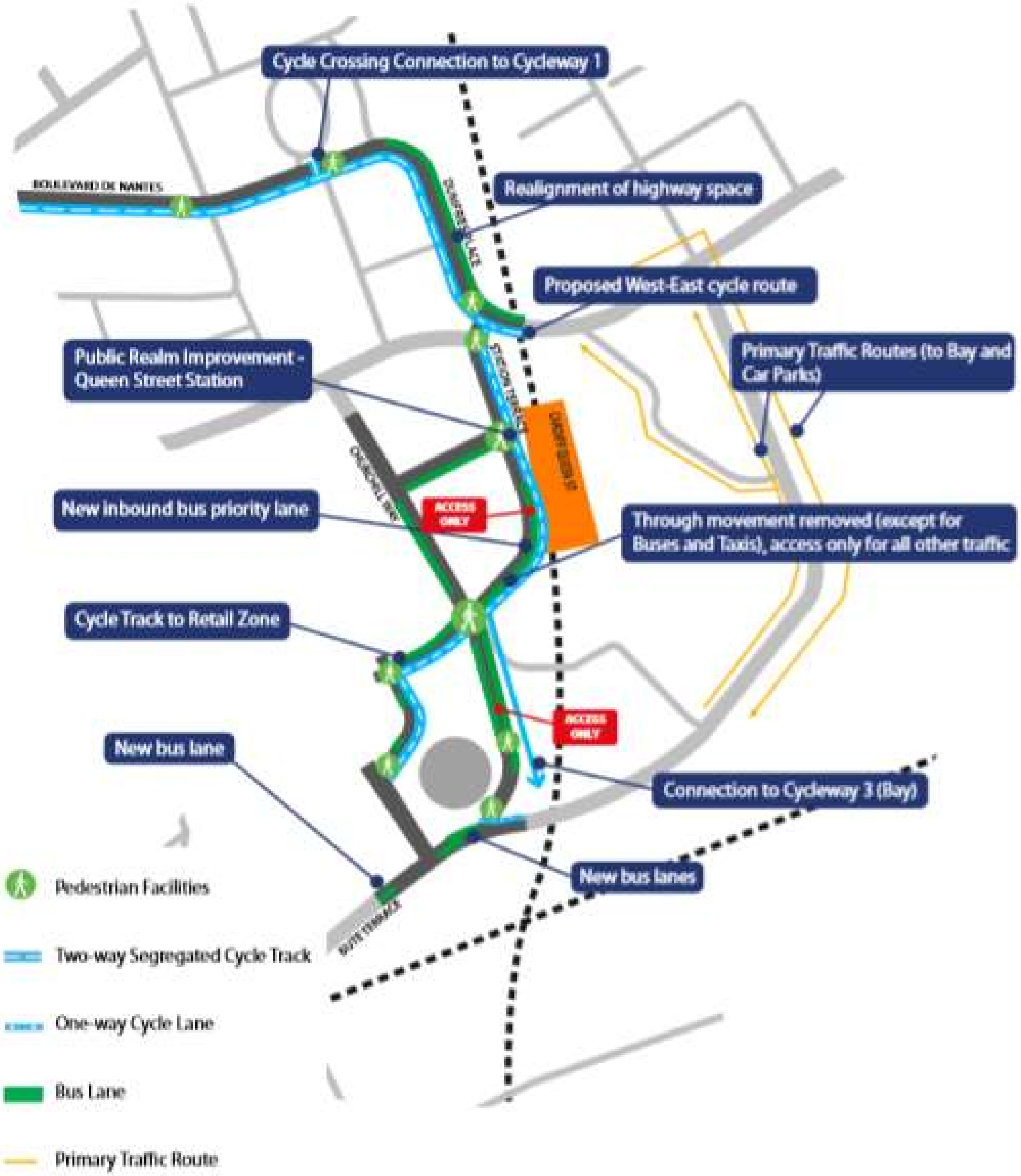
City Centre North

The main aim of this scheme is to bring Castle Street into Air Quality compliance by 2021 and install a primary Cycle Way along its length. The installation of the cycle lane and the reduction in highway space will allow for traffic to be reduced enough to target the air quality issue. Improved pedestrian crossings with countdown timers could also provide safety improvements for pedestrians.


Temporary Cycle Crossing
Primary East-West Cycleway
Improved pedestrian connections to the Civic Centre
Widened Pavements
Access loop
Reduction to two lanes of traffic
ACCESS ONLY
Potential Location of Bus Gate - No through access, bus only
Havelock Street arrangement reversed
Widened Pavements
Pedestrian Facilities
Two-way Segregated Cycle Track
One-way Cycle Lane
Bus Lane

City Centre East

The main aim of this scheme is to provide a new dynamic for the bus network, whilst connecting primary Cycle Ways and improving the pedestrian environment outside of Queen Street Station. This could be achieved through providing bus priority measure throughout the Station Terrace and Churchill Way areas that would provide new routes for buses, taking them away from the City Centre Air Quality Management Area and closer to key areas such as Queen Street Station and the shopping district. The new bus routing system is also key to allowing the Interchange to be accessed from its south entrance, and also work effectively on major event days. A primary Cycle Way could be installed to connect the east of the city centre with the City Centre Enterprise Zone, and join up all the other proposed primary Cycle Ways. Pedestrian improvements on Dumfries Place and Station Terrace could also improve safety for pedestrians and improve connections to Queen Street Station and the City Centre Enterprise Zone.



8 Do you support the overall design principles of these schemes, which aim to contribute to meeting the legal limits of NO2 in the shortest possible time?

Around two-thirds of respondents supported the proposals for the city centre schemes, with just under a fifth against:

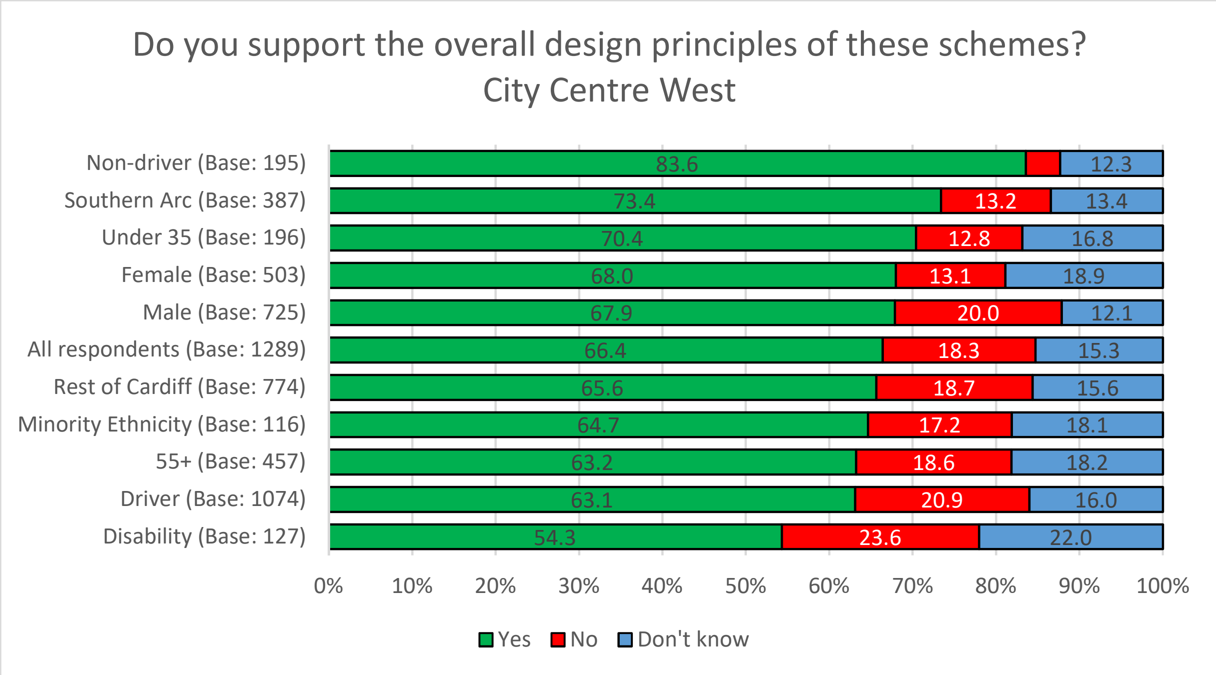
	City Centre West		City Centre North		City Centre East	
	No	%	No	%	No	%
Yes	856	*66.4*	848	*65.9*	854	*66.6*
No	236	*18.3*	237	*18.4*	230	*17.9*
Don't know	197	*15.3*	202	*15.7*	199	*15.5*
	1289	***100.0***	**1287**	***100.0***	**1283**	***100.0***

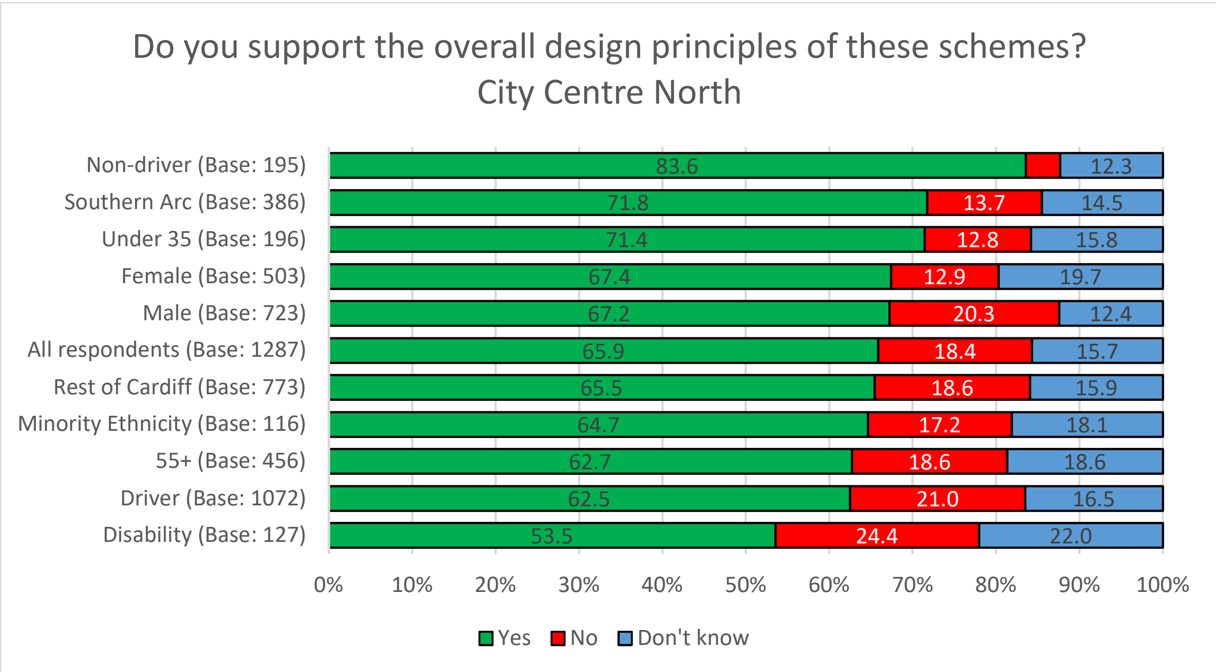
Support was highest amongst non-drivers, with over four-fifths in favour…

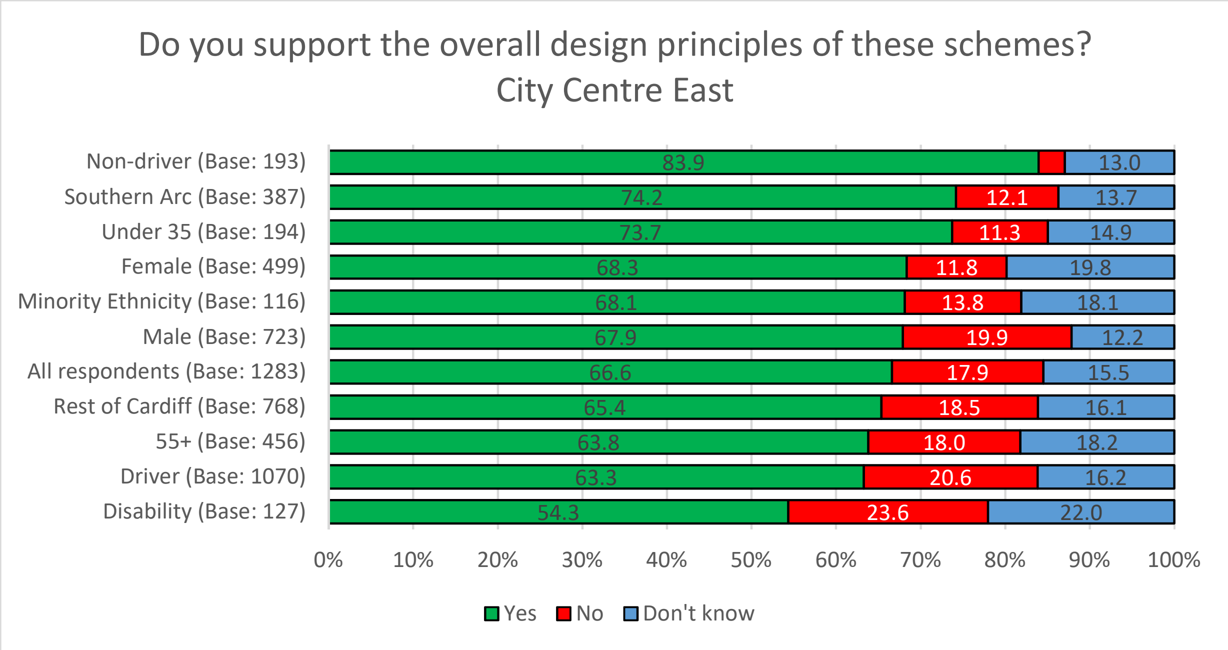
	City Centre West		City Centre North		City Centre East	
	No	%	No	%	No	%
Yes	163	*83.6*	163	*83.6*	162	*83.9*
No	8	*4.1*	8	*4.1*	6	*3.1*
Don't know	24	*12.3*	24	*12.3*	25	*13.0*
	195	***100.0***	**195**	***100.0***	**193**	***100.0***

…and lowest amongst respondents identifying as disabled, with just over half supporting the design schemes, and around a quarter against them:

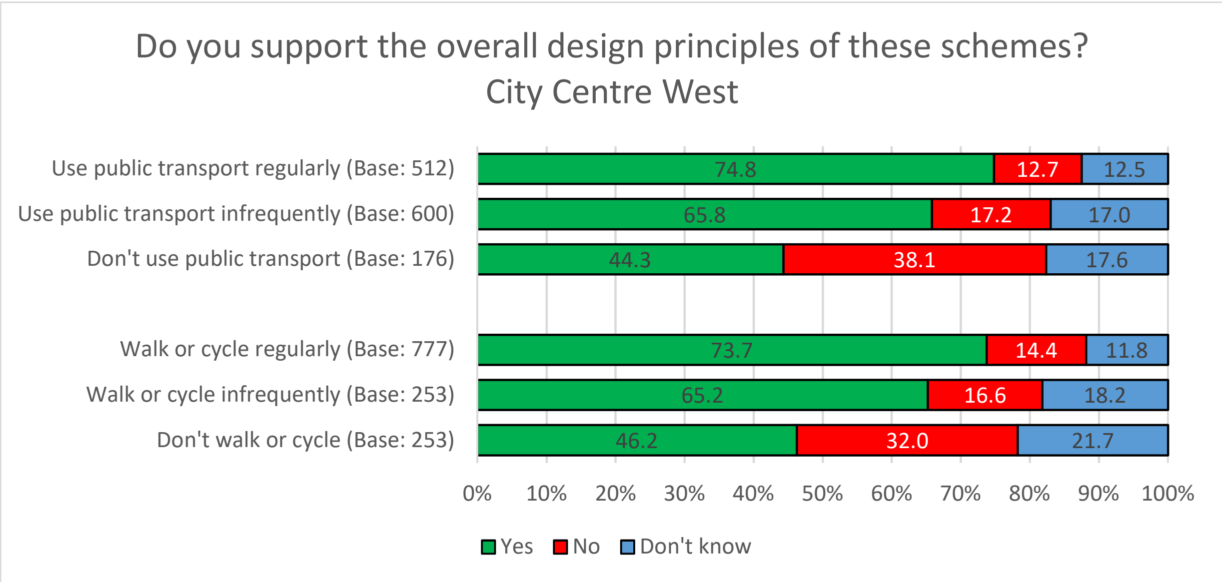
	City Centre West		City Centre North		City Centre East	
	No	%	No	%	No	%
Yes	69	*54.3*	68	*53.5*	69	*54.3*
No	30	*23.6*	31	*24.4*	30	*23.6*
Don't know	28	*22.0*	28	*22.0*	28	*22.0*
	127	***100.0***	**127**	***100.0***	**127**	***100.0***

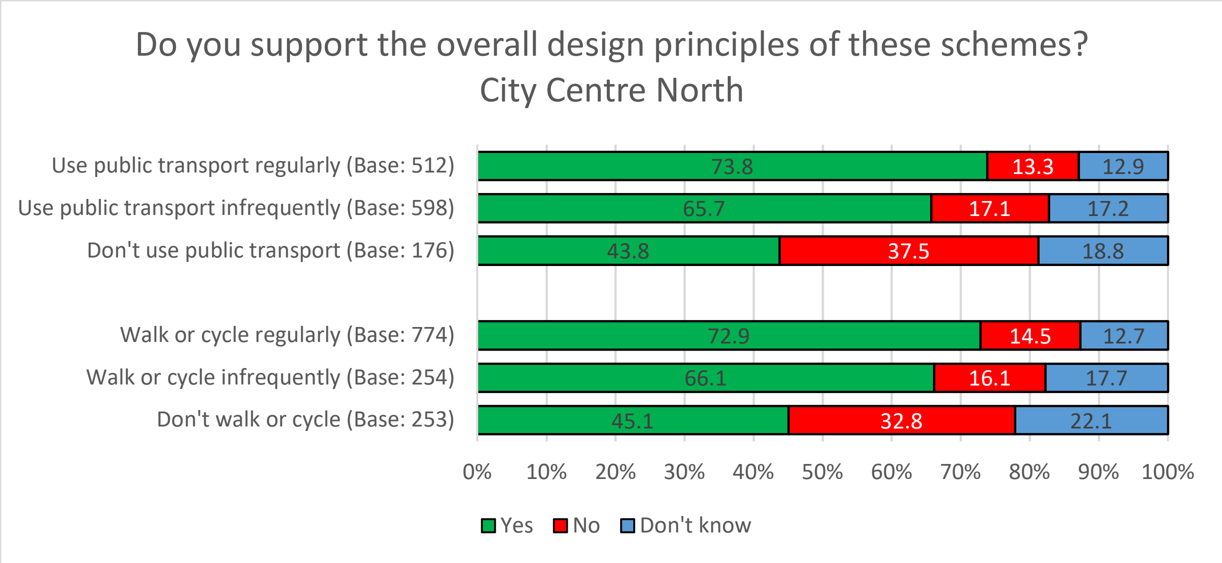

Do you support the overall design principles of these schemes?
City Centre West
Non-driver (Base: 195)
Southern Arc (Base: 387)
Under 35 (Base: 196)
Female (Base: 503)
Male (Base: 725)
All respondents (Base: 1289)
Rest of Cardiff (Base: 774)
Minority Ethnicity (Base: 116)
55+ (Base: 457)
Driver (Base: 1074)
Disability (Base: 127)
83.6
12.3
73.4
13.2
13.4
70.4
12.8
16.8
68.0
13.1
18.9
67.9
20.0
12.1
66.4
18.3
15.3
65.6
18.7
15.6
64.7
17.2
18.1
63.2
18.6
18.2
63.1
20.9
16.0
54.3
23.6
22.0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Yes
No
Don't know

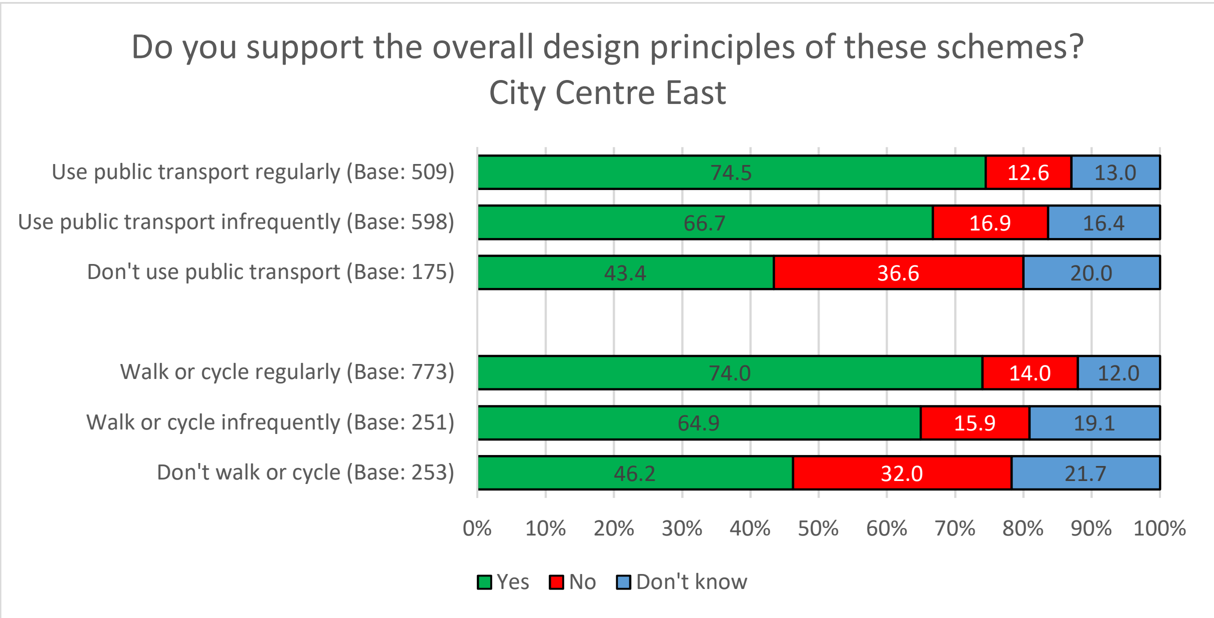

Do you support the overall design principles of these schemes?
City Centre North
Non-driver (Base: 195)
Southern Arc (Base: 386)
Under 35 (Base: 196)
Female (Base: 503)
Male (Base: 723)
All respondents (Base: 1287)
Rest of Cardiff (Base: 773)
Minority Ethnicity (Base: 116)
55+ (Base: 456)
Driver (Base: 1072)
Disability (Base: 127)
83.6
12.3
71.8
13.7
14.5
71.4
12.8
15.8
67.4
12.9
19.7
67.2
20.3
12.4
65.9
18.4
15.7
65.5
18.6
15.9
64.7
17.2
18.1
62.7
18.6
18.6
62.5
21.0
16.5
53.5
24.4
22.0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Yes
No
Don't know



Support for these design principles was notably lower amongst respondents who do not use public transport or active means of travel:




Do you support the overall design principles of these schemes?
City Centre North
Use public transport regularly (Base: 512)
Use public transport infrequently (Base: 598)
Don't use public transport (Base: 176)
Walk or cycle regularly (Base: 774)
Walk or cycle infrequently (Base: 254)
Don't walk or cycle (Base: 253)
73.8
13.3
12.9
65.7
17.1
17.2
43.8
37.5
18.8
72.9
14.5
12.7
66.1
16.1
17.7
45.1
32.8
22.1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Yes
No
Don't know


Do you support the overall design principles of these schemes?
City Centre East
Use public transport regularly (Base: 509)
Use public transport infrequently (Base: 598)
Don't use public transport (Base: 175)
Walk or cycle regularly (Base: 773)
Walk or cycle infrequently (Base: 251)
Don't walk or cycle (Base: 253)
74.5
12.6
13.0
66.7
16.9
16.4
43.4
36.6
20.0
74.0
14.0
12.0
64.9
15.9
19.1
46.2
32.0
21.7
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Yes
No
Don't know

9 Do you have any alternative suggestions on how traffic movements in the City Centre could be changed in order that the Council can meet its duty to improve air quality in the shortest possible time? Please provide evidence for this if possible.

A total of 578 comments were received for this question, which have been grouped into themes. The top three are shown below; a full list of themes can be found in Appendix 4.

Theme	No.	%	Example Comments
Traffic flow / light sequence / Road layout	179	*31.0*	*Re-phase traffic lights to reduce the amount of time spent waiting at red lights.* *Improve the road network for cars* *Remove speed humps, they cause drivers to accelerate and brake between them.* *Private vehicles should be allowed to turn left into Wood Street thereafter into St Mary Street: The current system forces East bound traffic westwards along Wood Street and through residential areas to get to Callaghan Square. A 1.8 mile journey for a distance of only 0.3 miles.* *Get rid of bus lanes, they are empty and cause traffic jams thereby increasing pollution.* *Rather than hindering the progress of private motor vehicles, it makes more sense to assist them in moving through the area. The longer a vehicle is in an area, the more pollution it will generate in that area.*
Improve cycleways / storage	137	*23.7*	*If you are going to make provision for more cyclists, please ensure there are appropriate cycle lanes. Cardiff at the moment does not feel safe for me as a pedestrian because of all the cyclists illegally cycling on pavements and jumping red lights at junctions. When you challenge cyclists about this you just get abuse.* *More secure, and monitored by City CCTV, bike racks for cyclists.* *I hope these routes don't just end, abandoning the cyclist. There would be a need to improve cycle storage too - maybe re purpose car storage sites* *Provide more cycling facilities inc routes and parking - ideally overlooked for maximum security and covered from the weather.* *Improved cycle safety and dedicated cycle lanes would hugely encourage more to use cycles, esp. when secure places for "parking" cycles be provided...*
Improve public transport	133	*23.0*	*I don't agree giving more priority to buses until they become at least useably reliable and cheaper.* *Sort out the buses so that they go to places that people need - rather than just the centre of town.* *Introduce affordable cleaner public transport before you start charging people* *Reduce car transport in the East with train stations on the existing line at Roath, Rumney, St Mellons and Marshfield*

A number of comments responses were received from Stakeholders and organisations in response to this question:

Healthy Air Cymru *

Sustrans Cymru are pleased with the proposals that Cardiff council are recommending to reduce illegal limits of air pollution in the city centre. The investment in progressive walking and cycling infrastructure is something we have been calling for, and we believe that when these plans are linked up to the walking and cycling developments that are taking place city wide, Cardiff will see a change in the way in which people move around. However, we would like to see Cardiff taking bolder action to encourage people to leave their cars behind.
Sustrans Cymru would like to see traffic removed from Cathedral Road to Boulevard de Nantes and Westgate Street, allowing access for busses, traders and people with a disability, but restricting access for the majority of private vehicles in the city centre. Air pollution is at crisis levels in urban centres around the world and removing traffic is one of the most effective tools local governments have to tackle it. Pontevedra, Northern Spain, serves as a model of the local transformation that removing traffic can bring. The city removed traffic from its 300,000 square metre city centre in 1999, bringing myriad economic, social and health benefits to its residents. As a result of the reduction in car use, the city has achieved a 70% drop in CO_2 emissions.
Castle Street is one of the city's oldest and most iconic locations and the impact of traffic and severance is notable, many people who come to visit Cardiff come to see the Castle and enjoy its grounds. Removing vehicles from this location would connect the castle to the city centre, improve commercial viability, and create (a place) an attractor for people to stop in and enjoy. We have seen this happen in Bristol where traffic has been removed from a number of key locations within the city. This has resulted in the creation of some of the most popular, iconic places within the city most notably College Green and Queen's Square which have been transformed from busy roads to green spaces where people can stop, relax, and enjoy the area. The severance caused by traffic on Westgate Street is also notable. Despite the stadium being a landmark, activity in the town centre stops at High Street, and the role Westgate Street is predominantly that of an arterial route for vehicles. Removing traffic from this area would have a similar effect as the closure of Castle Street. Linking the iconic Principality Stadium with the rest of the city centre and creating an attractive area for people who live in, and people who visit the city.
Removing traffic from both Castle Street and Westgate Street is achievable for Cardiff. Just this weekend Cardiff saw people of the city take over Castle Street on Cardiff Car Free Day, the space is also often closed when large events take place in the city, Westgate Street is also regularly closed to traffic on match days. This shows that the Cardiff council are already able to facilitate travel in and out of the city without this route open to private vehicles and the closure has the potential to seriously improve air quality in the city centre. Research from city closures across Europe show a huge drop in emissions when cars were removed from their roads. In September 2015 Paris went car free for the day, exhaust emissions were reduced by 40%. Similarly, during the London marathon route in 2018, estimates put the reduction in local air pollution at 89% in some parts of the city.

Unspecified organisation
Close Castle Street for traffic. Would become nice public space for people. Would create nice square in front of castle too and could introduce a cafe culture to the city (at the moment you can't as most outside areas are in the shade). Could have fountains etc. This will remove co2 from the biggest polluting area in the city overnight. As a minimum there needs to be a cordoned cycle lane from the bridge on this street to Bute Park. Currently it's dangerous. On Westgate St I've noticed it's a quiet street - could this be closed off to all traffic too?

Local Business
Ban taxis and buses from leaving their engines running whilst parked up

Unison Cardiff Central Young People's Officer
Yes, make the city centre are car free zone and introduce loads of cycling lanes. the measures the council aim to take, which currently cost millions won't successfully mitigate the damage of climate change, these changes are out of date and are not fit for purpose.

Cardiff University
The material presented was too diagrammatic to enable me to tell how cycle-friendly this would all be - the devil is in the detail! See for instance the disastrous arrangement for cyclists crossing North Rd to Tel-y-Bont

Environmental Health Lecturer
Remove multi storey car parks and ring fence funds to park & ride schemes which Cardiff appears poor at. See Oxford CC approach which is excellent - overnight P&R facilities; CCTV at P&R sites etc.

Castle Court Residents Association
Access and Parking facilities for Westgate Street residents is essential

Support Group for "Save the Trees at Suffolk House"
What a joke!!! Cardiff Buses have been cutting services after pleading with commuters to leave their cars and take the bus! Such a JOKE!!!

Elected Representative
Introduce a charging clean air zone

Professional Driver
Cleaner air is always a good thing but I don't care about the way you go about it. Paying out vast amount of money to bring down N02 gas and making the city centre a no go for cars will bring that centre to a full stop.

Professional Driver
The bus policy is obviously not working. Why is Cardiff Bus company stopping so many routes? Adjusting traffic light timings would be a good start to reducing congestion, therefore pollution.

Professional Driver
All this does is push the pollution to other areas. It just moves it. It doesn't solve the core problem

Professional Driver
Bus lanes for example are rarely used in most areas, bus drivers hate them, they are proven to be unsafe and taxi drivers use them like rat runs, in and out to get one car ahead.

Professional Driver
Footbridge connecting Queen St with castle area so pedestrians can cross freely, traffic will flow, less congestion and less emissions

Professional Driver
Cardiff needs more affordable car parks so people can access the city centre using their cars. A ring of multi-storey carparks around the centre would be beneficial... This would produce more shoppers using Cardiff stores.

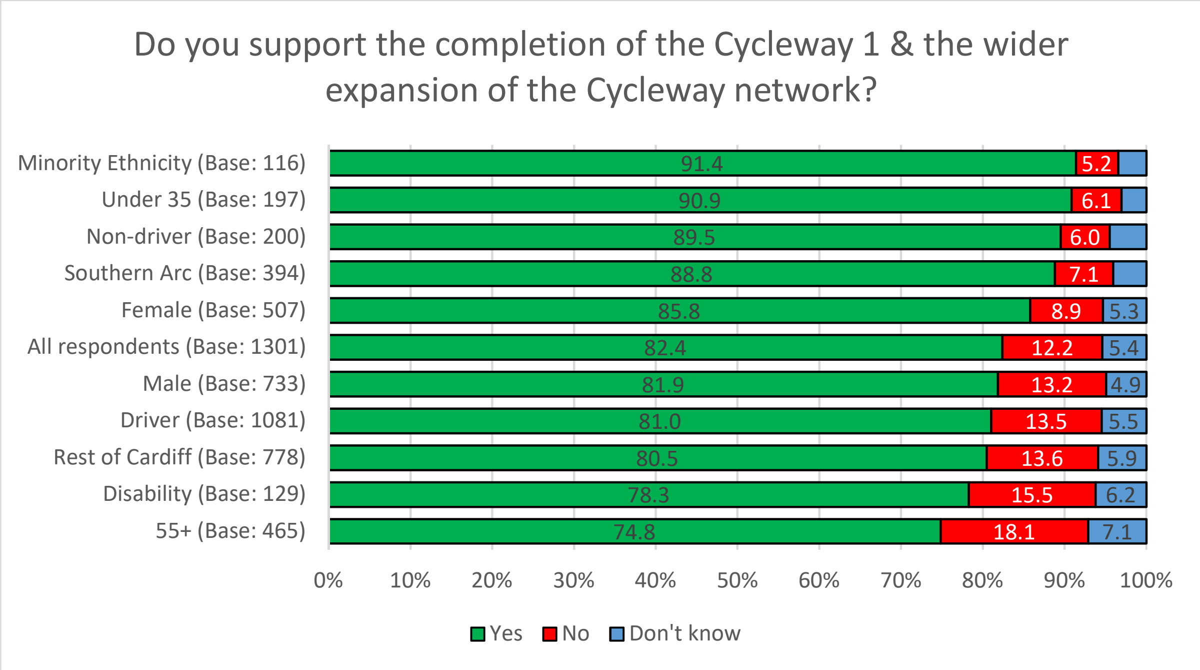
Professional Driver
Shut the city centre off and close all the shops down and build more student flats and stop everyone using the city centre. Also don't forget to put up the council tax again.

Professional Driver
Stopping traffic access on Station Terrace, which uses this road to park in St. David's car park would shunt all this traffic to either the central link road/A4160 in both directions heading into the centre or from the direction of Callahan Square. Traffic can be heavy on these roads already during busy periods.

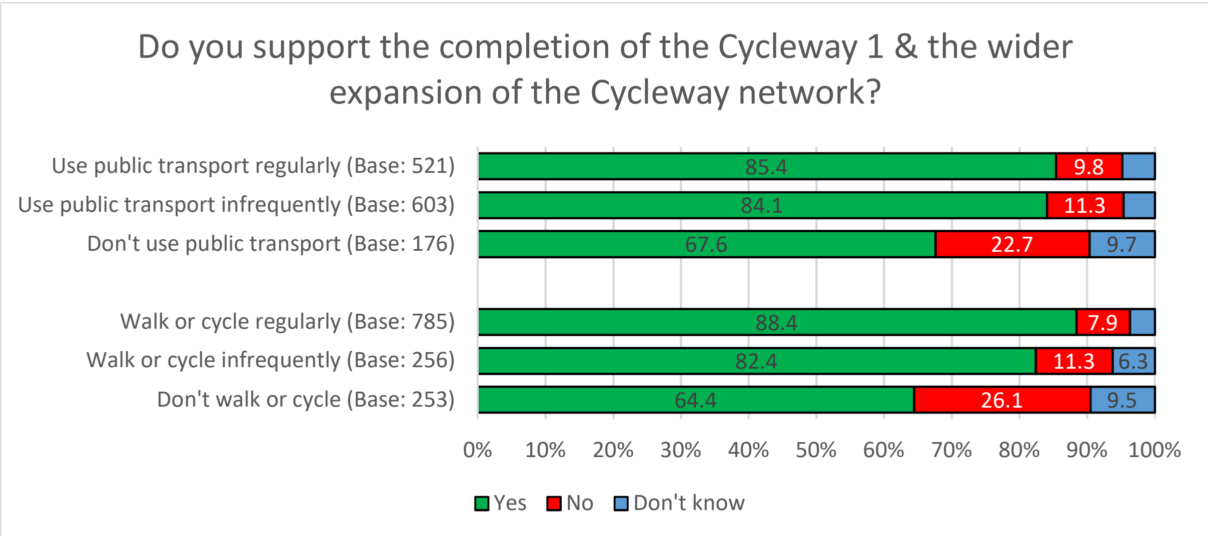
Active Travel and Cycleway C1 Completion

10 Do you support the completion of the Cycleway 1 (connecting the city centre to Cathays, University Hospital Wales, Heath and North East Cardiff) and the wider expansion of the Cycleway network?

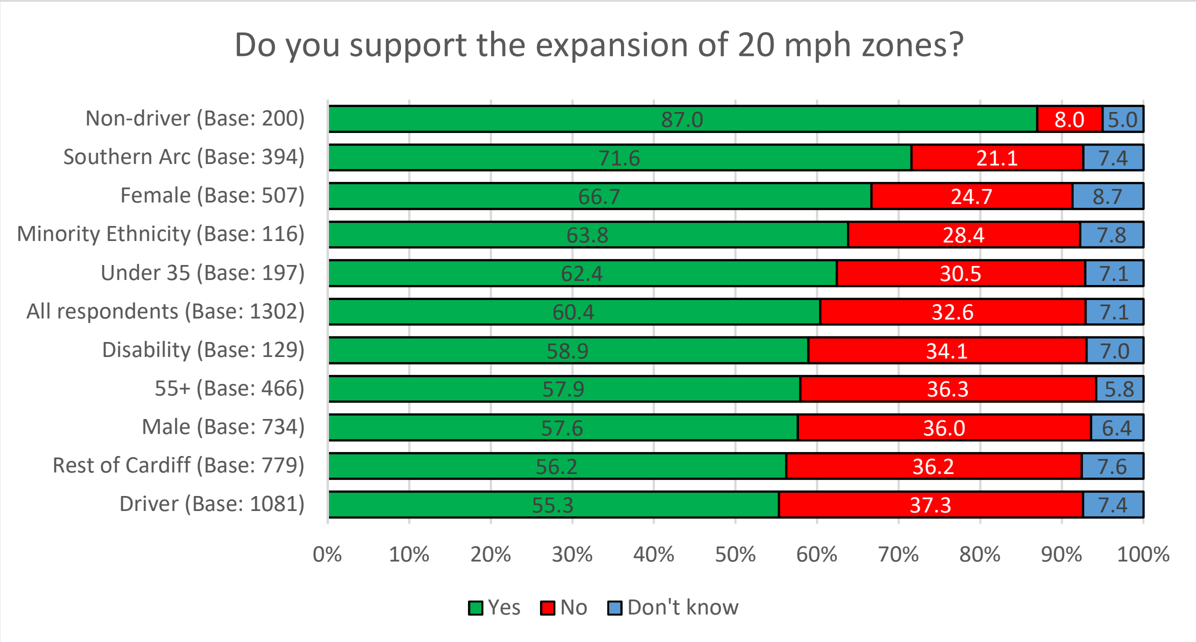
Support for the expansion of Cycleway 1, linking the city centre and North East Cardiff, and the Cycleway network as a whole was strong, with at least 74% of each of the demographic groups analysed agreeing with the proposals.



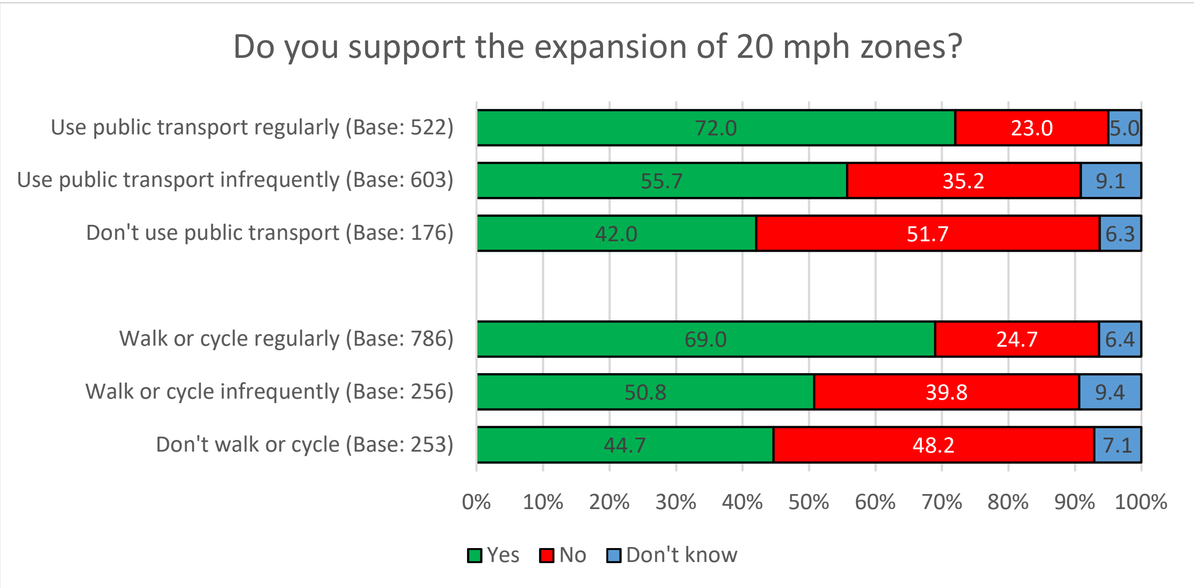
Unsurprisingly, support was highest amongst respondents who regularly use active means of travel, along with those who use public transport:



11 Do you support the expansion of 20 mph zones?



Again, support was lower amongst respondents who do not regularly use public transport, or active means of travel:



12 Are there any other measures you think the Council should be implementing in order to deliver compliance with the NO2 limit value in the shortest possible time? Please provide evidence for this if possible.

A total of 652 comments were received for this question, which have been grouped into themes. The top three are shown below; a full list of themes can be found in Appendix 5.

Theme	No.	%	Example Comments
Promote cycling / make it easier / more facilities	121	*18.6*	*Stop making poor quality painted cycle lanes, they will not attract anyone to cycling. Segregation, even where it hurts.* *Increased cycling infrastructure.* *Give cyclists and pedestrian right of way over traffic. Cycleways should be designed so that they don't have to stop for cars everywhere. Cars should be stopping for cyclists and pedestrians. The cycle route to the Bay is an embarrassment with gates blocking the cycle way at every intersection. It's good that the problem is being fixed now, but the fact that such a route was originally implemented highlights the fact that Cardiff council needs a lot of input from true cyclists and good cycle cities around the world in order to do things correctly and not as half measures again.* *Ensure budget is available for maintaining and expanding the cycleways each year with appropriate and secure bike parking facilities at appropriate locations* *Changing cycle ways and expanding them is good but I would like to see much more training and management of cyclists on the city's roads. Rush hours are already dangerous in N Cardiff because they're all over the road.*
Improve public transport	114	*17.5*	*An increase of public transport covering the whole of Cardiff, if you can make the trains better and more frequent and make the buses run on time and fund more routes around the city, people will rely on them more and thus drive less.* *Reduce cost of public transport and improve reliability and frequency. Until we can rely on transport we will continue to drive places*

			Improving the bus network so that the differences in journey times between using a private vehicle and using public transport are lessened. *Accessible bus routes throughout the city the connect with other public transport services i.e. rail* *Tram system, improved public transport, subsided public transport - currently more economical to drive and pay car park. Bus routes need improvement so you don't need to enter city centre, bus company needs subsidising*
Traffic calming / Flow	111	*17.0*	*Remove traffic humps and traffic calming measures, these result in speed up, slow down traffic, which INCREASE emissions. Smooth driving, which can be achieve only when traffic jumps are removed will actually decrease emissions.* *I am concerned that raised tables used to reduce traffic speeds in 20mph zones actually increase NO2 emissions. Vehicles tend to slow down when approaching and then accelerate after passing these road 'humps' and emit more NO2 by accelerating rather than maintaining the same speed.* *Make major routes for traffic able to go through all traffic lights at green if you stick at 30mph not have to stop at every traffic light* *Remove bus lanes that slow down traffic by condensing traffic into fewer lanes, creating more emissions.* *Too many pedestrian crossings add to the stop/start of vehicles, thus adding to pollution.*

A number of comments responses were received from Stakeholders and organisations in response to this question:

Healthy Air Cymru *

Sustrans Cymru would like to see Cardiff council being holistic in its approach to sustainable transport, and investing in linking up all forms of transport so that walking and cycling is an easy and accessible option. Rail stations should be active travel hubs making it easier for commuters, locals and visitors to get active. This includes safe cycle storage at all main transport interchanges, notably Cardiff Central station, Cardiff Queen Street station, and when it is built the bus interchange in Central Square.

Elected Representative
Open St Mary St/High St and make one way in & one way out with Westgate St

Unspecified Organisation
Close off as many city centre roads from traffic. Close Castle St. This would cut emissions over night

Cardiff University
A wider congestion charge covering the city, better funded and more coherent bike lanes and subsidised/expanded bus provision.

Academia – RTPI Member
The cycle route with bollards by Lidl off Caerphilly road is shocking, it's always full of glass and can't be ridden on, complete waste of space and money. Road cleaners can't keep it clear of glass which means even less road space for cyclist and cars. Can't be used. Also no advertising of the new law to give cyclist 2 metres of space. Cycling in Cardiff is awful, and the worst culprits are Cardiff bus.

Cardiff University
Encouragement through schools & other educational institutions for greater use of cycles. But this needs to be linked with better provision of secure cycle storage at such institutions and also across the city (e.g. at railway stations - & not just Cardiff Central). There also need to be far more installations for securing bikes in the city centre. I gave up cycling in to do shopping because the bike stands in Queen St., etc., are far too far apart (when you have heavy shopping you cannot carry it so far between bike stands before loading it onto the bike (to take the weight), and anyway are totally inadequate in number.

Cardiff University
Clear air charge for commercial vehicles. Electrification of public transport. (Reintroduce trams!) Incentivise commuter schemes (cycle-to-work, compulsory parking charges for employees, etc). Perhaps park and ride?

Environmental Health Lecturer
Remove traffic; better P&R facilities; better cycle parking areas with appropriate security and safe routes. Cambridge have cycle car parks withe excellent security

Castle Court Residents Association
Discussions are pending with the Council

Community Watch
Yes - protect green spaces - reduce overdevelopment

Support Group for "Save the Trees at Suffolk House"
Yes, STOP giving developers of new build permission to fell trees. Trees are our lungs, they above all absorb carbon dioxide. For instance, we have lost our campaign to save the trees at Suffolk House, especially the older massive Copper Beech facing the Infants Nursery and

Old People's Home. Where is the sense of the Planning Committee in giving the Builders/developers permission to chop down these beneficial life giving trees?

Elected Representative
Charging Clean Air Zone

Professional Driver
I believe that implementing catalyst to reduce the N02 gasses effect can be done by "Selective Catalytic Reduction systems are seen as an efficient technology necessary to achieving emission standards. They work by adding ammonia either in the form of Ad Blue a liquid NOx reducing agent, or directly as a gas, using cartridges to the exhaust gases. This then reacts in a catalytic converter with the nitrogen oxides coming from the diesel engine to release harmless nitrogen and water vapour at the tailpipe."

Professional Driver
Remove speed humps

Professional Driver
Built out bus stops, 20mph zones and more bus lanes have been introduced to cause congestion and to try to force people out of their cars. This has not happened. The poor air quality is self-inflicted and I predicted this 10 years ago. A good excuse to introduce a congestion charge to again, screw the motorist. You should be ashamed of your selves.

Professional Driver
Traffic light systems often introduces traffic jams and idle running vehicles, smart systems that allow traffic to flow when red lights are not need should be implemented, even part time on off systems could be used.

Professional Driver
Remove bottle necks so that traffic can flow faster and not remain stationary by castle

Professional Driver
Stop running half-empty buses. New legislation needed in parliament.

Professional Driver
I think you are on the right track but don't rule out modern diesel engined buses.

Professional Driver
Make every council employee use public transport. Lead by example.

13 Are there any other comments you would like to make about the Council's Air Quality Strategy and Action Plan?

A total of 572 comments were received for this question, which have been grouped into themes. The top three are shown below; a full list of themes can be found in Appendix 6.

Theme	No.	%	Example Comments
Support the proposal	118	*20.6*	*You can't escape the current screams for progress in reducing emissions in today's world - I'd love for Cardiff to be at the forefront of this charge. Let's not focus on the short term, let's focus on being the benchmark city that others want to copy. Electric buses, electric taxis, more restrictions on the wider area for general motor vehicles, real investment in cycle schemes for all residents of Cardiff - I support the schemes proposed but urge you to take this opportunity to really shake things up and pioneer Cardiff as being THE GREEN CITY of the UK. Let's attract people and businesses who have a strong social responsibility - by being THE green city we'll reap the rewards. Let's make Cardiff stand-out very prominently for all of the right reasons - this is our chance!* *I'm glad steps are being taken not only for reasons of public health and wellbeing, but also as a response to climate change.* *Looks great, now get on with it. It can't come quick enough!* *I support many of the suggestions made so far, but at the same time should wish the Council to proceed with caution in order to limit any expensive mistakes, and also to gain the backing of the public and businesses.* *Pleased to know that the Council is taking action to improve air quality. The more we can do so much the better.*
Be more ambitious	91	*15.9*	*It isn't nearly enough. Why not be a leader in Europe rather than catching up?* *It's neither ambitious nor strong enough to make the kind of impact to improving air quality and reducing carbon emissions that we require.*

			Very 1 dimensional. Need a holistic approach that includes minimising car use, cleaner cars and carbon absorption.
Promote / Encourage / Enable Active Travel	68	*11.9*	*Introduce more rent a bikes, they have and are so successful.* *Many of the measures are welcome but there is a long way to go before it is safe and pleasant to cycle in Cardiff. Perhaps developing some of the lanes behind the terraced houses in Heath and other parts of the city as cycle paths would be an inexpensive and safe way forward* *I'd like to see how the council plans to address cycle security. Improved access has to come with a level of confidence that my bike will be there when I return from my visit to the city centre. Cycle theft it seems is an easy crime with low levels of detection.* *Make as many safe cycle routes to town and through town as possible. Many cycling commuters cannot get through the city safely*

A number of comments responses were received from Stakeholders and organisations in response to this question:

Elected Representative
Slowing traffic & closing streets would make it worse, not better

Unspecified Organisation
These are small steps that won't tackle the issue. You'll still be non-compliant and I might make court action. To resolve this you have to be bold and close roads. It's quick, easy and efficient solution

Local Business
Please don't introduce congestion charges or similar as it will harm trade

Cardiff University
Needs more buses, need to encourage a modal shift for those who want to come into or through the City Centre.

Academia – RTPI Member
Yes - don't just focus on the city centre, focus on residential areas where most of your population live and play. And not just the existing areas - your proposals in north Cardiff are an air quality nightmare waiting to happen for existing residents and now would be the most optimal time to act.

Cardiff University
20mph limits are pointless in that they have a compliance rate close to zero. Traffic calming measures typically result in increased braking and acceleration (so more brake dust and NO2).

Environmental Health Lecturer
No - appropriate the Council meets it

Community Watch
Stick to existing policies regarding protection of green spaces and conservation areas- stop allowing developers to destroy trees etc., prior to planning applications.

Professional Driver
It's ok for you to reduce the speed limit to 20mph while engine idle speed can run up to 20 mph it is damn hard to stick to a twenty mph limit. The police, your own buses and taxi can't keep to it. Why is it that whenever you alter any road you bring the speed limit down not by five but ten. You are driving the private car off the road, and that will cost jobs that will reflect on you through taxation. For goodness sake stop the lowering of the speed limit or face a title wave of protesters.

Professional Driver
Ignoring the elephant in the room, of the council's huge expansion of the city housing. Resulting in more traffic and more pollution.

Professional Driver
I had a conversation with a Councillor some time ago about pollution with a particular emphasis on traffic light timings, which is a cheap and easy way to alleviate congestion and pollution is certain areas. He showed no interest at all and treated me as an imbecile. It's a big turnaround now though.

Professional Driver
Too little too late. This should have been implemented by now not being proposed

Professional Driver
Consider not just the city centre as being the main area, residential areas should be given the highest priority when planning and not just the so called deprived areas, as it is often just wasted money.

Professional Driver
Remove bus lanes where buses don't use them, Cryws Rd junction with Albany Rd. Allow cars to use bus lanes during off peak hours

Professional Driver
Bring in trams to the city centre. Those trams can take punters to bus stops outside the city centre when buses can go to the required destinations.

Professional Driver

If you persist in decreasing the use of cars the City centre will suffer. Empty shops don't pay rates. The John Lewis car park shows parking around the centre can be convenient and affordable. A ring of such car parks would make Cardiff a good destination city.

Professional Driver

As a driver, any expansion of Cycle Lanes and Pathways would be a welcome addition to the city of Cardiff. But these need to be implemented in such a way that finds the best possible balance between cycle safety and efficiency with the needs of road vehicles.

Engagement Events

Four Engagement Events were held in the city centre, giving members of the public the opportunity to discuss the proposals with the Project Team in greater depth. In total, 76 people attended:

April 13th: Angel Hotel (Prince of Wales Suite – Ground floor) – 22 attendees
April 20th: Central Library (level 3) – 13 attendees
May 4th: Angel Hotel (Rhymney Suite – Floor 1) - 25 attendees
May 11th: Central Library (level 3) – 16 attendees

Respondents attending these events were also invited to complete feedback forms and leave further comments or questions in addition to completing the survey; 23 forms were received. Satisfaction with the event, level of information, knowledge of the facilitator, and suitability of the room and facilities were high:

Question	Score out of 5
Overall, how satisfied are you with the event today?	4.2
I felt I had sufficient information	4.5
I felt the facilitator was knowledgeable on the subject	4.8
The room and facilities were suitable	4.1

Twenty respondents provided their contact details in order to be kept up-to-date on the project.

More than half of the comments made supported the proposals, or pushed for them to be more ambitious:

Let's get this up and running ASAP. Keep up the good work.

This is excellent value for money at ~£20-30m and a massive improvement on present arrangements

Well done, but – continue to be ambitious e.g. remove NCP car park in front of Principality Stadium and make the whole area welcoming as well as reducing pollution in Westgate St

It could be more ambitious! The recent declaration of a climate emergency provides a political context that would allow for more radical approaches that reduce air pollution even more – especially in regards to getting more electric buses.

Very informative and helpful

Concerns were raised that the consultation had not been promoted more widely, or that the venue was not suitable:

This consultation should not be "hidden" away in an obscure venue for a mere 4 hours. The one in the Angel Hotel could've been more accessible in a vacant shop in Working Street.

Signpost the event more prominently

Lack of bike parking at venue

Other concerns were raised, including the impact on people living in the city centre, and suburbs adjacent to it that could be negatively impacted by the proposals:

Access to my home – Landmark Place, Churchill Way – is often obstructed by traffic. The 'No Right Turn' into N Edward Street contributes to this congestion and I still have to use the right lane to access my home

Concerned about the highway through Llandaf. The pollution needs to be monitored constantly.

Concerns about shifting of traffic to Lower Cathedral Rd

Demographics

Which of the following best describes you? Please tick one box only

	No	%
A member of the public	1263	*97.2*
An elected representative	5	*0.4*
Representing an organisation or group	12	*0.9*
A professional driver	10	*0.8*
Academia	10	*0.8*
	1300	**100.0**

Do you drive any of the following? Please tick all that apply

	No	%
Car	1062	*82.8*
Motorbike	43	*3.4*
Van / LGV	42	*3.3*
Lorry / HGV	7	*0.5*
I don't drive	200	*15.6*
	1282	**-**

Respondents could select more than one option, so totals may not add to 100.0%

Is this...?

	No	%
Petrol	649	*60.4*
Diesel	442	*41.2*
Bio-diesel	1	*0.1*
Electric	20	*1.9*
Other	28	*2.6*
	1074	**-**

Respondents could select more than one option, so totals may not add to 100.0%

'Other' types of vehicles specified were Hybrid (22 mentions) and LPG (3 mentions).

Do you walk or cycle other than for recreational purposes? (e.g. to get to work/ school/ shops)

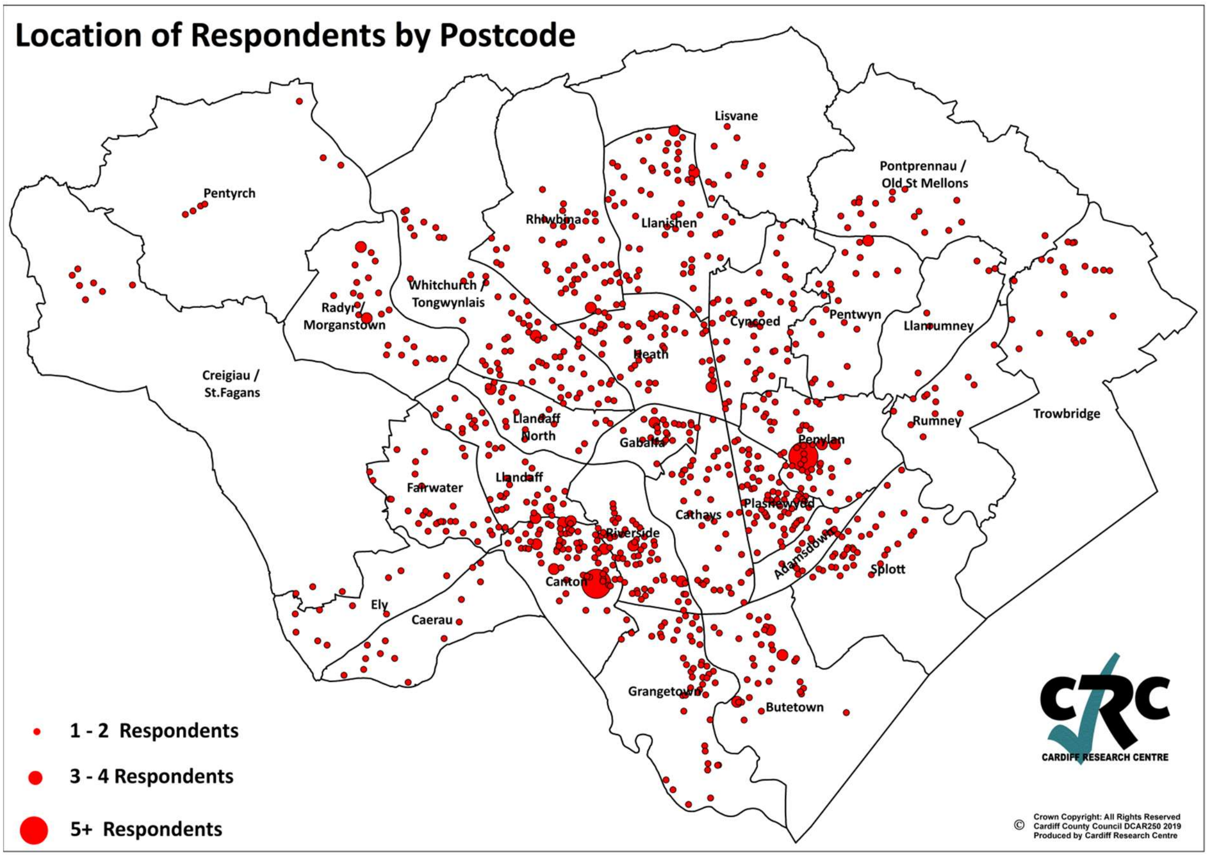
	No	%
Yes, regularly	787	*60.7*
Yes, but infrequently	256	*19.8*
No	253	*19.5*
	1296	**100.0**

Do you use public transport?

	No	%
Yes, regularly	522	*40.1*
Yes, but infrequently	603	*46.3*
No	177	*13.6*
	1302	**100.0**

So that we can target our services across the city, please provide your postcode:

1,238 respondents provided their postcode; the map below identifies the home location of respondents living in Cardiff (postcodes provided showed that a number of respondents taking part in the survey were resident outside of the city).



Are you...?

	No	%
Female	507	*39.5*
Male	735	*57.3*
Other	5	*0.4*
Prefer not to say	36	*2.8*
	1283	***100.0***

What is your age?

	No	%
Under 16	2	*0.2*
16-24	27	*2.1*
25-34	168	*13.1*
35-44	294	*22.8*
45-54	284	*22.1*
55-64	247	*19.2*
65-74	184	*14.3*
75+	35	*2.7*
Prefer not to say	46	*3.6*
	1287	***100.0***

Do you identify as a disabled person?

	No	%
Yes	129	*10.1*
No	1090	*85.0*
Prefer not to say	63	*4.9*
	1282	***100.0***

Please tick any of the following that apply to you: (Tick all that apply)

	No	%
Deaf/Deafened/Hard of Hearing	73	*21.0*
Learning Impairment/difficulties	8	*2.3*
Long-standing illness or health condition	125	*36.0*
Mental Health Difficulties	50	*14.4*
Mobility Impairment	88	*25.4*
Visual impairment	17	*4.9*
Wheelchair user	10	*2.9*
Other	19	*5.5*
Prefer not to say	78	*22.5*
	347	**-**

Respondents could select more than one option, so totals may not add to 100.0%

What is your sexual orientation?

	No	%
Bisexual	36	*2.9*
Gay Man	55	*4.4*
Gay Woman/Lesbian	10	*0.8*
Heterosexual/Straight	906	*72.7*
Other	7	*0.6*
Prefer not to say	232	*18.6*
	1246	***100.0***

Do you regard yourself as belonging to any particular religion?

	No	%
Yes	411	*33.3*
No, no religion	823	*66.7*
	1234	***100.0***

	No	%
Buddhist	7	*1.7*
Christian	332	*82.4*
Hindu	1	*0.2*
Jewish	3	*0.7*
Muslim	8	*2.0*
Sikh	0	*0.0*
Other	18	*4.5*
Prefer not to say	34	*8.4*
	403	**100**

What is your current Marital or Civil Partnership status?

	No	%
Married / Registered Civil Partnership	688	*55.2*
Single	218	*17.5*
In a long-term relationship	226	*18.1*
Separated/Divorced	57	*4.6*
Widowed	28	*2.2*
Other	29	*2.3*
	1246	**100**

Do you consider yourself to be Welsh?

	No	%
Yes	811	*65.2*
No	432	*34.8*
Prefer not to say	0	*0.0*
	1313	***100.0***

What is your ethnicity?

	No	%
White: British/English/Northern Irish/Scottish/Welsh	1057	*84.6*
White: Irish	22	*1.8*
Other White background	57	*4.6*
Mixed/Multiple Ethnic Groups: White & Asian	5	*0.4*
Mixed/Multiple Ethnic Groups: White & Black African	0	*0.0*
Mixed/Multiple Ethnic Groups: White & Black Caribbean	3	*0.2*
Other Mixed/Multiple ethnic background	1	*0.1*
Asian/British Asian: Bangladeshi	4	*0.3*
Asian/British Asian: Chinese	1	*0.1*
Asian/British Asian: Indian	3	*0.2*
Asian/British Asian: Pakistani	1	*0.1*
Other Asian/British Asian ethnic background	2	*0.2*
Black/British Black : African	3	*0.2*
Black/British Black : Caribbean	2	*0.2*
Other Black/British Black ethnic background	0	*0.0*
Other Ethnicity: Arab	0	*0.0*
Other Ethnicity: Czech	0	*0.0*
Other Ethnicity: Gypsy/Irish Traveller	1	*0.1*
Other Ethnicity: Japanese	0	*0.0*
Other Ethnicity: Polish	1	*0.1*
Other Ethnicity: Yemeni	0	*0.0*
Other Ethnicity	10	*0.8*
Prefer not to say	76	*6.1*
	1249	***100.0***

Are you pregnant, or have you given birth within the last 26 weeks?

	No	%
Yes, pregnant	8	*0.7*
Yes, given birth	5	*0.4*
Neither	1145	*93.2*
Prefer not to say	71	*5.8*
	1229	***100.0***

Do you have Caring responsibilities?

	No	%
Yes	183	*14.4*
No	1022	*80.7*
Prefer not to say	62	*4.9*
	1267	***100.0***

Appendix 1 – Key Stakeholders

Contract Management Team

Statutory bodies
WLGA
Natural Resources Wales
Public Health Wales
Policy officers at Welsh Government who oversee the funding

Cabinet
Elected Members
Public Services Board
Public Protection Committee Members
Clean Air Steering Group
Shared Regulatory Service Joint Committee
Environmental Scrutiny Committee
MP's
AM's

Environmental Campaign Groups
Friends of the Earth
Client Earth
Healthy Air Cymru *
British Lung Foundation Wales
British Heart Foundation Wales

Business Improvement District (on behalf of city centre business)

Unions
GMB
Unison
Unite

Active travel campaign groups
Sustrans
Cardiff Cycling Campaign
Living Streets
Sustain Wales

Taxi forum
Cardiff Hackney Alliance (200-300 drivers)
Taxis – Private hire operators and Hackney carriage

Cardiff Bus

Royal Mail

Stagecoach

New Adventure Travel

National Express

Associated British Ports

Federation of Small Businesses Wales

Alliance of British Drivers

Road Haulage Association

Society of Motor Manufacturers and Traders

Community Transport Association

Chartered Institute of Environmental Health

Institute of Air Quality Management

Environmental Protection UK

Environmental Industries Commission

Confederation of Passenger Transport

Travel campaign groups
RAC
AA

Community groups
Westgate Street Residents Association

Businesses
Castle Street
Angel Hotel
The Castle Arms

Nisa Stores
Elevens Bar and Grill
Revolution
Chicken.com
Greazy Vegan
Fabulous Welshcakes
Nata & Co
Castle Welsh Crafts
Holiday Inn
Westgate Street
Mango House
Box UK Ltd
Bar 44
Tiny Rebel
Zerodegrees
Queens Vaults
Brew Dog
National Probation Service
O'Neill's
Central Square
Hugh James
BBC Cymru Wales
Lynq
Entrepreneurial Spark
MotoNovo Finance
Rightacres Property
Milk & Sugar
M&S Simply Food

City Centre East
Dumfries Place
Arrivo Autobus
Evans Cycles
Berry Smith LLP
Friscon Foods Ltd
Optimum Credit
AXA Insurance
Geldards

Appendix 2 – Open-ended responses to Q3
Do you have any other comments regarding the introduction of cleaner buses in Cardiff?

A total of 496 comments were received for this question, which have been grouped into the following themes:

Please note, responses will add to more than 100% as more than one theme could be covered by a single answer

Theme	No.	%	Example Comments
Support the proposal	99	*20.0*	*An excellent idea. I use the bus regularly and wholeheartedly support this plan.* *I think this would be a quick easy win and fully support it* *Wholly in support, regardless of cost* *Do it all over the city, not just the city centre. How wonderful would it be if we had a bus station that could charge buses as they waited for passengers?* *Way to go.* *I'm very supportive of measures to update public transport provision and reduce pollution and am glad to see it prioritised.*
All buses to be electric/ULE/green	94	*19.0*	*36 electric buses is not enough. We need at least 90% of buses to be electric and the other 10% to meet the lowest emission standards.* *What is the point of upgrading buses to cleaner diesel when the aim should be electric? Cardiff Bus bought diesel as a cheaper option to electric, Cardiff Council is not providing enough charging points so this smacks as a short term saving to gloss over a short sighted investment plan.* *All buses and Council vehicles should be replaced by less polluting electric vehicles.* *All of the buses should be electric. I cough in the mornings at different times of the year from the bus exhaust and pollution I breathe in while riding in the city centre.* *100% of buses in Cardiff should be electric, including coaches and stagecoach services not just Cardiff Bus*

Other issues with buses - Reliability, cleanliness, Demand, Dedicated Bus station, Accessibility	83	*16.7*	*The bus routes need to be looked at. As they are incredibly long for no reason - a journey on the bus in Cardiff will take around the same time if you are walking to your destination. The busses in Cardiff are a time wasters and unreliable in term of time and even showing up at all sometimes as I lived in other cities and that was not the case. So no matter what kind of bus it is me as a professional and have no time to waste I will not trust Cardiff buses to commute. I did not feel the need to get a car till I moved to Cardiff unfortunately. Due to the disappointing service.* *get rid of bendy buses as they snarl up the traffic by blocking the road* *Buses are the worst pollutants in Cardiff currently, really discouraging me to cycle, I end up stopping and coughing so many times I get stuck behind one. Also, they are terribly managed, extremely unreliable and polluting while carrying 2 or 3 passengers* *This is only good if you stop cutting bus routes, buses run on time, and they stop being cancelled.* *I am disappointed the bus station at Central Square is still incomplete. It sends out the wrong message about a commitment to public transport.*
Amend timetables/ routes	76	*15.3*	*They should only run when needed, empty buses aren't needed and increase pollution and traffic issues* *There should be a continuous monitoring of passenger numbers, frequency of bus services* *Make them more useful for users!! The buses are too infrequent & don't go where people want, the whole system is totally unsuitable for disabled people* *Introduce more bus routes, and a wider timetable. Cancelling routes last month, and having no buses running Sundays and nights, will force people to take their cars to their destination.*
Alternative Transport/ Technological options	67	*13.5*	*Consider biomethane and hydrogen options* *Buses are dirty- can't we have trams? I don't use buses because they're a lower form of transport*

			Whilst a Tramway would require the infrastructure of track laying resulting in roadworks, Trolley bus systems operate on overhead cabling and batteries which could have rechargeable capabilities and are ideal in urban environments *I draw attention to the Alstom Primove system of bus charging rather than the obtrusive Balfour Beatty system trialled previously.*
As soon as possible	57	*11.5*	*Long overdue* *This should be done ASAP* *A great idea, should be done as quickly as possible*
Encourage public transport use	43	*8.7*	*Doesn't matter how clean buses are if no-one uses them - buses need to be more frequent and less expensive to encourage people not to drive in the first place* *Make the whole of the centre of Cardiff car free. Cardiff is over populated now and more should be done to keep the centre and surrounding areas free from cars. CCC should provide taxi buses who should be the only transport available around a 5 mile radius of Cardiff central. The suburbs are now too saturated with cars queuing to get into the centre of town on a daily basis, cars should be parked at provided bays and then get bus taxis into town.* *That they have more of them at nights and on weekends so that I can use them instead of having to take the car as there is at present no bus for me to use*
Cost of this change - who is to pay, no fare rises	39	*7.9*	*The cost to the Council will be huge but the benefits to our environment are huge.* *Instead of retrofitting other buses and wasting money just replace them when needed with the new electric buses* *If WG doesn't pay who will?*
Current cost/ integration of Public Transport	36	*7.3*	*A better integrated system, Oyster card for trains and buses. All buses regulated so same ticket can be used on different companies and concessions.* *do not increase fares and do not cut any more bus routes* *Make public transport free*

Idling engines a problem	33	6.7	*Clear protocol on idling needed* *Need to ensure both buses and taxis don't wait with their engines running; exhaust fumes and particulates are aimed directly at people waiting with children being closest to the emissions.*
Apply to all operators	32	*6.5*	*This must apply to all buses operating in Cardiff* *What about other buses and coaches that 'visit' the city?*
Discourage car use	21	*4.2*	*The introduction of cleaner buses is welcomed, however the reduction of car use should be a priority.* *Less cars would help more*
Dispute Bus pollution / Electric vehicle benefits	18	*3.6*	*I doubt whether buses are the chief culprit for pollution.* *Current production of electricity is still too dependent on pollution emitting technology for electricity to be deemed a more desirable fuel source.*
Against retrofitting	*17*	3.4	*I think retrofitting is a waste of money. Ultimately they will be replaced with electric, so do it now, the fuel savings will make it pay. Air quality is a pressing issue.* *Concentrate on purchasing new buses; may be some smaller buses as some routes do not need big buses all the time and we need more frequent services*
Charging points	11	*2.2*	*If a central bus station was finally built then this would probably significantly help as there would be a centralised hub of where the buses start and charging points could be based in the same area which means that between changeovers and transfers to buses - buses could be charged. I would envision that charging points would be above each bus stop within the bus station so that buses could be charged up before they go off to do their route.* *Will there be enough charging stations around the city?*
Encourage Active travel	9	*1.8*	*I'd still prioritise cycling infrastructure, despite supporting these changes* *However, changing the most polluting buses is only part of the solution. Disincentivising car travel and*

			incentivising other means like cycling is even more important in the city centre.
Other vehicles to be upgraded	5	*1.0*	*If we can do this for buses can a program for delivery lorries and transport vans follow.* *Other council vehicles (e.g. bin lorries) should also be converted to electric if possible*
Traffic flow	5	*1.0*	*Recent road changes are causing traffic jams which cannot help air pollution can it* *Pollution is caused by too many traffic lights in the city centre with cars sat their waiting for lights to change*
Miscellaneous	29	5.8	*Make sure the bus drivers learn how to drive safely around cyclists* *Strictly controlled management of public money is essential while pursuing a clean air policy and it should be phased in over time in a well scheduled programme* *Only use electric vehicles if you're sure electricity is generated in a green way*

Appendix 3 – Open-ended responses to Q7
Do you have any further comments or suggestions on how to change taxi licensing rules to improve air quality in the city?

A total of 442 comments were received for this question, which have been grouped into the following themes.

Please note, responses will add to more than 100% as more than one theme could be covered by a single answer

Theme	No.	%	Example Comments
All taxis should be Low Emission	86	19.5	*Has to be all electric* *We need to go full electric / hydrogen on all taxis in Cardiff by 2025, and support rapid development of renewable energy sources of electricity / hydrogen.* *Complement stricter emission standards with incentives to upgrade vehicles to electric ones.* *Not to issue new licences unless hybrid or fully electric after 2021* *All taxis should be electric or hybrid.*
Taxi firms/ drivers should pay	68	*15.4*	*Taxis are the responsibility of the operator - public money should not be spent to pay for their cleaner vehicles.* *My answer to question 6 is 'no' because I would have concerns that public money is paying for someone who privately owns a vehicle, to get a newer vehicle, which they could sell at some point and keep the full amount of money. Should they have a caveat that if they cease operating within 5yrs of the grant, they repay the grant, otherwise they could receive the grant, retire within a month, and keep the car/grant. I would love money to be given to me to replace my diesel car! What about self-employed people i.e. builders, who travel the whole city. They are providing a service to the public too, the same as taxi drivers - it's all private work, to earn a living. It's discriminatory if only taxi drivers are helped.* *Taxi drivers will not need grants - if cars are disincentivised from the city centre (with taxis exempt) then their revenue will be higher* *Subsidy is inappropriate otherwise everyone should get it*

Discourage idling	61	*13.8*	*Taxis (and buses) often sit empty with their engines running. This should not be allowed and measures should be put in place to discourage this practice* *Prohibit and enforce measures to prevent idling engines whilst taxis are waiting.* *A rule that states that taxis engines must be switched off when they are not driving. You see entire ranks of them all with their engines on whilst waiting for customers just because they want the radio on.* *Ban buses and taxis from being allowed to idle their engines at stops of any kind*
Management of scheme - financial, criteria for acceptance, history of taxis, time for implementation, incentives	53	*12.0*	*Issuing grants to taxi drivers should come with certain conditions such as repayment of grants if a private vehicle ceases to be used for taxi purposes within a certain time limit* *Grants offered must be ring-fenced and monitored* *Should be an interest free loan and not an outright grant. This would be in order to discourage financial misuse of the system.* *Taxis provide a vital service and should not be driven out of business as a result of these changes. If financial support is not available additional time to transition should be given*
Enforce rules	49	*11.1*	*I think there are too many taxis in the city centre which allows drivers to abuse the licensing arrangements and decline short fares etc. Stricter licensing and enforcement is required.* *Stricter enforcement of speed limits for taxis* *I think the rules on taxis should be stricter than the proposals in order to really minimise pollution. In the area I live in, many families own taxis which they appear to use as a family car for the school run (thus getting away with stopping on yellow lines and parking illegally) - I would be unhappy to know taxpayer's money was being used to basically upgrade taxis that are primarily used as family cars to abuse normal driving/parking rules.*
Too many taxis	44	*10.0*	*Might I suggest a restriction on the number of taxis operating in the city as currently many hackney cab drivers think they're entitled to rank in bus and cycle lanes, even during the day, because official ranks are already full but this only adds to congestion as buses*

			and cycles swerve out into lanes for cars and commercial vehicles. *There are a lot of old taxis in Cardiff, I wonder how some of them ever get through the MOT!* *restrict the amount of plates and badges* *License less of them! Far too many for the trade to be sustainable!*
Improve infrastructure/ Public Transport	36	*8.1*	*Improved cycle lanes and public transport to reduce demand for taxis.* *Expand bike hire scheme and provision for cycling rather than continuing to promote motor transport as the best way forward in a small, flat city* *Improve public transport and lessen amount of taxis* *Low emission vehicles only work when there is the appropriate infrastructure to support - is there plans to install charging points at the regular taxi stopping points?*
Investigate other schemes	32	*7.2*	*Is there not a retrofit option for cars? As with the buses? Could grants for these be offered where possible?* *Barcelona is very well-served by hybrid vehicles, mainly Toyota.* *Why not follow the same model as London? The new all-electric London taxi would work in Cardiff - I'd propose spending the money, sought from the Welsh Government, in providing the required charging infrastructure and forcing all new taxis to be fully electric. Cardiff's geography is not huge, so we'd be a great city to embrace this without any issues with 'range anxiety'. I see so many taxis in Cardiff belching out black fumes, I'm surprised to read the policy only allows vehicles up to 10 years old, I feel like some taxis look much older. Euro 6 isn't good enough in my view - no way near good enough.*
May affect No of taxis/demand on service	31	*7.0*	*Taxis are already scarce enough, don't reduce them further!* *Beware unintended consequences, e.g. could result in fewer and more expensive taxis, which could lead to more unregulated private cars.* *If there is inadequate financial support for taxi owners to change, we are likely to see a reduction in taxis and*

			the a rise in price, which in turn will encourage people to bring their private cars more into the city centre, especially for pickups from bus or train stations
Support proposal	29	*6.6*	*No, looks logical* *I think it will be a very good idea to get this done as soon as possible.* *Time to stop talking and crack on with it*
Should apply to all taxis - even those registered outside Cardiff	26	*5.9*	*Enforce the same emissions requirements on taxi's registered outside Cardiff that enter the city boundary* *Will the changes in licensing ensure that taxis from outside Cardiff can't get around the proposed new regulations?* *This can only work if taxis from neighbouring local authorities are banned from operating in Cardiff, which clearly can't happen. This is a prime example of where a national policy can work, but a local council 'going it alone' simply won't result in the benefits that they think it will. It also makes Cardiff taxi drivers operate at a significant disadvantage to other areas if they have to fund improvements to their own vehicles where others don't*
Loan not grant	17	*3.8*	*Should be an interest free loan and not an outright grant. This would be in order to discourage financial misuse of the system.* *A grant should be offered with a 50% match in funding from the driver/company. This option should be available to small businesses who drive in the city centre for deliveries, services etc.* *Drivers of cars should be responsible for upgrading their cars not the government, grants should only be provided if drivers pay these back over time.*
Don't increase fares	14	*3.2*	*Forcing taxis to update their vehicles will only drive up prices, and will reduce the amount of people using taxis* *If these measures are put through costs to customer will go up - which would be unfair.*
Issues with Taxis in Cardiff/ Poor service	12	*2.7*	*Taxi service is a shambles in Cardiff run to make money and customer needs a long way second* *Why are taxis exempt from using indicators!*
Training for drivers needed	11	*2.5*	*All taxi drivers should not be licensed unless they have a thorough knowledge of the city on a par with ' The*

			Knowledge' process in London. There should be a minimum a level of cleanliness to all Taxis operators. All Taxis should carry GPS trackers to add additional level of safety and security to passengers and drivers. *Ensure taxi drivers have training to share roads with cyclists*
Unsure of criteria/ standard	10	*2.3*	*A taxi's life is relatively short - this could be achieved by natural "wastage". You are re-licensing and issuing new licenses now so why would you need money to implement it? What would the 5.5 million be needed for?* *I'm uncertain why the Euro 6 standard is not required at testing points, not just at first application*
Offer grants to other vehicles	5	*1.1*	*If you are going for a grant for Taxi's why not HGV's LGV's and personal cars.* *Will this apply to Uber? What about delivery vehicles e.g. pizza delivery cars or supermarket vans?*
Be more ambitious	4	*0.9*	*These proposals do not go far enough. In some situations, this is even a step backwards. These proposals are indicative of a lack of courage.* *Yes many Cardiff taxis are disgraceful and very old, and need to be taken off the road. Standards need to be stricter for sure and I don't think these proposals go far enough.*
Miscellaneous	40	*9.0*	*When queuing at taxi ranks, customers should be allowed to choose electric vehicles, to ride in, even if they are further down the queue* *Modern cars will help.* *stop encouraging people to go into the city centre for huge events* *I would be concerned about the increased costs of taxi journeys. This would particularly impact disabled people who are unable to use other forms of transport, for example who do not have the ability to navigate the bus system, or who are frequently subject to abuse and harassment on the bus system.*

Appendix 4 – Open-ended responses to Q9

Do you have any alternative suggestions on how traffic movements in the City Centre could be changed in order that the Council can meet its duty to improve air quality in the shortest possible time? Please provide evidence for this if possible

A total of 578 comments were received for this question, which have been grouped into the following themes:

Please note, responses will add to more than 100% as more than one theme could be covered by a single answer

Theme	No.	%	Example Comments
Traffic flow/ light sequence/ Road layout	179	*31.0*	*Re-phase traffic lights to reduce the amount of time spent waiting at red lights.* *Improve the road network for cars* *Remove speed humps, they cause drivers to accelerate and brake between them.* *Private vehicles should be allowed to turn left into Wood Street thereafter into St Mary Street: The current system forces East bound traffic westwards along Wood Street and through residential areas to get to Callaghan Square. A 1.8 mile journey for a distance of only 0.3 miles.* *Get rid of bus lanes, they are empty and cause traffic jams thereby increasing pollution.* *Rather than hindering the progress of private motor vehicles, it makes more sense to assist them in moving through the area. The longer a vehicle is in an area, the more pollution it will generate in that area.*
Improve cycleways / storage	137	*23.7*	*If you are going to make provision for more cyclists, please ensure there are appropriate cycle lanes. Cardiff at the moment does not feel safe for me as a pedestrian because of all the cyclists illegally cycling on pavements and jumping red lights at junctions. When you challenge cyclists about this you just get abuse.* *More secure, and monitored by City CCTV, bike racks for cyclists.* *I hope these routes don't just end, abandoning the cyclist. There would be a need to improve cycle storage too - maybe re purpose car storage sites*

			Provide more cycling facilities inc. routes and parking - ideally overlooked for maximum security and covered from the weather. *Improved cycle safety and dedicated cycle lanes would hugely encourage more to use cycles, esp. when secure places for "parking" cycles be provided...*
Improve public transport	133	*23.0*	*I don't agree giving more priority to buses until they become at least useably reliable and cheaper.* *Sort out the buses so that they go to places that people need - rather than just the centre of town.* *What a joke!!! Cardiff Buses have been cutting services after pleading with commuters to leave their cars and take the bus! Such a JOKE!!!* *Introduce affordable cleaner public transport before you start charging people* *Reduce car transport in the East with train stations on the existing line at Roath, Rumney, St Mellons and Marshfield*
More pedestrianisation	65	*11.2*	*More pedestrianisation and an electric tram/metro.* *I welcome the proposals. When the city centre is closed due to events (rugby...), it is a pleasure to walk and cycle in the city centre. I understand that without improved public transport, education, changes of lifestyle, it is not possible to have a pedestrianised Castle Street; but it would be ideal.* *Pedestrianise all of city centre... no cars to enter city from 1 mile.*
Close city centre to cars	55	*9.5*	*Ban Diesel cars over a certain age from city centre* *Completely close roads to cars in the city centre and only allow: taxis, buses, delivery lorries and bikes. The only roads available are for car parks* *Castle Street should be closed as a through route to private motor vehicles. This worked well during the NATO summit.*
Congestion charge/Levy polluting vehicles	54	*9.3*	*Introduce a charge for going through the city centre at peak times* *Impose charge for "dirty" vehicles* *We would like to see a Clean Air Zone to restrict vehicles in the city centre wards*
Move problem elsewhere	48	*8.3*	*The aims are laudable, however shifting traffic onto other roads may significantly increase pollution levels there.*

			All this does is push the pollution to other areas. It just moves it. It doesn't solve the core problem
Reduce Car usage	44	*7.6*	*Perhaps introducing a pool commute benefit (allowed access to bus lanes if the car has 4/5 commuters?) for private vehicles that travel through these areas* *Nice start, but not ambitious enough. We really must reduce car use in Cardiff and that requires a serious shift in policy and thinking. This is tinkering at the margins.*
Low Emission transport	32	*5.5*	*Encourage use of electric cars by residents, as well as taxis and buses.* *Build a tram network, zero emissions!*
Accessibility considerations	32	*5.5*	*You have failed to meet needs of disabled by providing proper transport hub where they can change buses, coaches and easily access trains. I suspect this is illegal.* *Need to make sure disabled people can still drive where they need to*
Cheaper public transport	30	*5.2*	*I think if city centre buses were free for all users, it would have a big impact on air pollution and reduce the number of cars on the roads.* *Affordable public transport that is INTERGRETATED is the most important thing to ensure that clean air charging zones don't kill city centre.*
Parking	27	*4.7*	*Remove parking spaces in the city centre to encourage people to use public transport/active travel options* *Increase availability of car parking spaces so that less time is spent queuing.*
Stop vehicles idling	22	*3.8*	*Stop cars running their engines when halted for long periods, e.g. queuing for the John Lewis car park. Evidence: As an asthma sufferer, wheezing when passing that queue.* *Ban taxis and buses from leaving their engines running whilst parked up*
Be more ambitious	20	*3.5*	*Drastic, bold action is needed* *The designs seem intended to cause as little disruption to car traffic and, as such, lack sufficient ambition and risk not shifting behaviour. So e.g. the West route goes through and existing park route meaning less cost and inconvenience to cars, yet creating conflict with other park users e.g. dog walkers and ends with a very steep climb near the cathedral. It's all got the feeling of something watered down to be more palatable to motorists. A bolder approach is needed to create real change. It will end up costing much more in the long term.*

Enforcement	17	*2.9*	*I fully support 20mph zones in the city centre and more should be done to implement these - including devolving powers to the council to regulate and monitor compliance with fixed cameras and issuing Fixed Penalty Notices.* *Enforce illegal parking.*
Need more info	17	*2.9*	*I need more information on the above to comment.* *I am unsure about the design principles as would need more detail, and diagrams to comment*
Impact on businesses/ residents	15	*2.6*	*These plans will destroy the businesses in the city centre because they won't be reachable by car. The council and Welsh Govt need to accept reality. The car isn't going anywhere and if places aren't reachable by car then no one will go there and businesses will fail.* *I feel that fundamentally this plan doesn't take into account city centre residents (perhaps clear from a lack of information/invitation to the public consultations). Whilst we do not have parking at Golate Court, there will need to be provision in place for residents to receive deliveries/ be able to drop-off/pick-up nearby, either routinely or when moving in or out of the block. The current plans do not make any of these issues clear, and I would appreciate far better communication with residents for the next stage of consultations.*
Against the proposals / will make things worse	14	*2.4*	*Public transport priority has been shown to produce traffic congestion* *Reducing number of lanes won't reduce the number of cars on the road but will lead to more congestion which will not help reduce emissions*
Introduce new technology	10	*1.7*	*Introduce air quality towers that suck in the fumes and carbon trap them in the filters release air back and use the carbon to produce diamonds for resale or use in construction tooling* *Sort out your strategy to allow terraced houses to have electric charging points so we can buy electric cars*
Education / engagement	8	*1.4*	*Work with large companies and organisations based in the centre in order to educate management and staff on the alternative options available to them in regards to transport. Partnerships should be built to encourage people who work and/or visit the city centre to not bring a car. Cheaper public transport, car share schemes, more bicycle stands, better bus routes etc.* *Pollution around schools must be high and engaging children and teenagers into the plan would be a good opportunity*

Stop building houses	7	*1.2*	*Refuse planning permission for any building that does not have connections to public transport that is available regularly 24/7, 365 days p.a between that building and local services and the city centre.* *The Council seems to rely on making driving so slow and difficult that drivers will give up - this doesn't deter people when journeys are essential but simply makes pollution worse by causing jams and gridlock (increasingly common in Cardiff where housing is built with no thought as to how people will get to work).*
20mph limit	5	*0.9*	*I would like all residential areas to be 20. For some reason the council seem to shy away from doing this despite the safety benefits and give in too much to car owners* *Remove 20mph zones go back to 30! When driving in a 20 zone to keep at 20 I have to remain in second gear with high revs, in a 30 zone I can go into 4th gear at low revs so less pollution.*
Cost of change	4	*0.7*	*Postpone until finances become less restricted* *Waste of money*
Miscellaneous	37	*6.4*	*Any scheme should allow a high quality tariff-free route from all parts of Cardiff to the Central rail station - these schemes do not seem to provide for good uncharged routes to Central.* *Electric cars are not cleaner than fossil fuel cars- electric cars use more fossil fuels in the energy creating process used to create the electricity - in nuclear power stations etc.* *Car drop off points where passengers can safely get out of cars to access the city centre on foot while drivers do not have to drive into the city centre* *Probably a question of trial-and-error so be prepared to alter and progress measures but not retreat.*

Appendix 5 – Open-ended responses to Q12
Are there any other measures you think the Council should be implementing in order to deliver compliance with the NO2 limit value in the shortest possible time? Please provide evidence for this if possible.

A total of 652 comments were received for this question, which have been grouped into the following themes.

Please note, responses will add to more than 100% as more than one theme could be covered by a single answer

Theme	No.	%	Example Comments
Promote cycling / make it easier / more facilities	121	*18.6*	*Stop making poor quality painted cycle lanes, they will not attract anyone to cycling. Segregation, even where it hurts.* *Increased cycling infrastructure.* *Give cyclists and pedestrian right of way over traffic. Cycleways should be designed so that they don't have to stop for cars everywhere. Cars should be stopping for cyclists and pedestrians. The cycle route to the Bay is an embarrassment with gates blocking the cycle way at every intersection. It's good that the problem is being fixed now, but the fact that such a route was originally implemented highlights the fact that Cardiff council needs a lot of input from true cyclists and good cycle cities around the world in order to do things correctly and not as half measures again.* *Ensure budget is available for maintaining and expanding the cycleways each year with appropriate and secure bike parking facilities at appropriate locations* *Changing cycle ways and expanding them is good but I would like to see much more training and management of cyclists on the city's roads. Rush hours are already dangerous in N Cardiff because they're all over the road.*
Improve public transport	114	*17.5*	*An increase of public transport covering the whole of Cardiff, if you can make the trains better and more frequent and make the buses run on time and*

			fund more routes around the city, people will rely on them more and thus drive less. *Reduce cost of public transport and improve reliability and frequency. Until we can rely on transport we will continue to drive places* *Improving the bus network so that the differences in journey times between using a private vehicle and using public transport are lessened.* *Accessible bus routes throughout the city the connect with other public transport services i.e. rail* *Tram system, improved public transport, subsided public transport - currently more economical to drive and pay car park. Bus routes need improvement so you don't need to enter city centre, bus company needs subsidising*
Traffic calming / Flow	111	*17.0*	*Remove traffic humps and traffic calming measures, these result in speed up, slow down traffic, which INCREASE emissions. Smooth driving, which can be achieve only when traffic jumps are removed will actually decrease emissions.* *I am concerned that raised tables used to reduce traffic speeds in 20mph zones actually increase NO2 emissions. Vehicles tend to slow down when approaching and then accelerate after passing these road 'humps' and emit more NO2 by accelerating rather than maintaining the same speed.* *Make major routes for traffic able to go through all traffic lights at green if you stick at 30mph not have to stop at every traffic light* *Remove bus lanes that slow down traffic by condensing traffic into fewer lanes, creating more emissions.* *Too many pedestrian crossings add to the stop/start of vehicles, thus adding to pollution.*
Discourage car use / car share / car free days	100	*15.3*	*People living outside of Cardiff should be restricted to driving on 4 out of 5 designated days only.* *Congestion zone or car free day , say Sunday (except for busses and emergency vehicles - as they do in Rome)* *Taking a car needs to be very unattractive, high parking fees and fines. Attractive public transport with low prices, increase acceptance of cycling by*

			car drivers. Introduce car sharing systems to make people give up cars, introduce park and ride spaces for drivers from the valleys (parking lots + public transport/ bike schemes at the city border) *Decreasing the number of cars driving in Cardiff seem the most obvious and effective way to reduce pollution.* *Can the numbers of cars driving into Cardiff be reduced? More park and ride facilities? I don't know the answer - but I am heartily fed up with seeing about 95% of cars in the rush hour with only one person in them.*
Enforcement	57	*8.7*	*Enforce parking restrictions. Enforce laws regarding idling engines.* *Legal enforcement and monitoring of 20mph zones.* *Start enforcing illegal parking in all areas of the city. Too many roads get blocked by people parking illegally & the vehicles are left there for substantial periods of time. Aggressively act on these & people will take notice that you are being serious about pollution, speeding up traffic flow, using public transport or cycling or walking.*
Charge to drive in city centre	48	*7.4*	*The introduction of a congestion charge for private cars and vans. Strict rules on polluting lorries that are essential for delivering and collecting goods from stores and shops etc. Old polluting lorries should be banned* *Charging for private cars will reduce this mode of transport and encourage greener ways of travelling.*
Improve infrastructure	45	*6.9*	*Finish the A4232 link road to take traffic around the south of the city. The only reason there's so much traffic on Newport Rd/Blvd De Nantes is the combined failure of the Council and WG to complete this road. Should be dual carriageway from M4 Junction 33 right through to A48M/M4 Junction 29 as originally intended. Sort the traffic light programme in town to maximise throughflow. Your current attempts to simply annoy people out of their cars by making it difficult and time-consuming to navigate the city obviously aren't working.* *Need to think bigger and invest in new roads and routes*

Reduce cost/Free public transport	42	*6.4*	*Free bus travel for all children, the school run is a major contributer to air pollution in Cardiff.* *Improve and reduce cost of existing forms of public transport and ease of access to them*
Incentivise low emission vehicles	36	*5.5*	*Allow ULEVs and EVs to use Bus Lanes. Encourage electric car use via free\subsidised parking and/or charging.* *Grants for businesses to switch to ZE ways of moving goods*
Implement charges	30	*4.6*	*Ban on all diesels, or at least a huge tax as in the Netherlands (£1000 per car).* *Clear air charge for commercial vehicles. Incentivise commuter schemes (cycle-to-work, compulsory parking charges for employees, etc.).*
Park & Ride	30	*4.6*	*Is there any value in increasing the number of park and ride points to help minimise the traffic into the city? Are they used effectively and if not what could be done to improve take up?* *Introduce congestion charge if enough park and rides spaces available*
Implement technology	27	*4.1*	*Real time air quality monitors, that show the air quality, to the public on site* *Why not have massive fans along castle street to keep the air circulating so that NO2 can disperse?*
More charging points	27	*4.1*	*install electric charging points around the city and along terraced streets* *Provision of public electric vehicle charging points throughout the city*
Other Transport options	27	*4.1*	*Why are electrified trams not being considered like in other cities?* *Increase other transport options - ferry services, rickshaws, small electric trams, even bikes with side cars! Queen street - St Mary Street - Hayes - Churchill Way could be a brilliant circular minim tram route for shoppers, with connections with bus stops/car parks*
Improve greenery	26	*4.0*	*Plant more street trees and make use of moss walls which can filter high volumes of air* *Plant more trees in new developments, the new BBC building is a concrete eye sore. Where are the gardens, living walls, roof gardens, wildflowers,*

			grass? Carbon sinks of all sorts need expansion. Businesses in the centre of Cardiff could make a huge differences if they planted things like vertical gardens etc.
Transport to school	24	*3.7*	*Create no waiting zoned around schools at start and finish times. Give greater publicity to ANY instances where the 40 micrograms per cubic metre limit is breached, not just the 80% figure. The 80% method hides the impact on school kids in particular, taking into account periods of lower pollution when the kids are not there, i.e. holidays and weekends.* *Offer school buses that were previously withdrawn meaning parents end up driving children to school*
Pedestrianisation	21	*3.2*	*More pedestrianised areas especially near schools and nurseries* *I think we need to make it more pleasant for pedestrians and not just cyclists. I don't like walking through Bute Park - or even on some pavements - because of very fast and aggressive cyclists. Please can the Council crack down on pavement cyclists, and set rules for shared spaces?*
Low emission / cleaner vehicles	19	*2.9*	*All Local Authority buildings should have Electric Pool Cars and Electric Chargers for staff. There should also be a scheme to encourage use of Electric pool cars in other businesses through incentives and charges. There should also be reduced parking charges for electric cars, especially at Park and Ride car parks which keep traffic out of the city.* *Why did the council stop purchasing LPG powered vehicles? There must be 500 plus small and medium sized vehicles that the Authority uses…*
Parking	17	*2.6*	*Reduce the number of car permits per household - only 1 + 1 guest permit* *https://www.centreforcities.org/blog/workplace-parking-levy-answer-cities-transport-congestion-problems/*
No idling	15	*2.3*	*No vehicles left running in residential areas when parked idling* *Introduce laws, backed by personal fines, forbidding all drivers of vehicles with traditional engines leaving them idle whilst parked, or picking up/dropping off.*

20 mph	15	*2.3*	*Remove 20mph zones as these increase pollution - cars are less efficient at low speeds - data is flawed as its spreading the pollution over a longer time period rather than reducing it.* *20mph zones should be the only such speed for vehicles within Cardiff - it is way safer, less polluting and a lot easier to "police" if this were the "normal" speed*
Suppress new housing developments	13	*2.0*	*Stop building so many houses in the city which mean more cars travelling into the city. The road and rail networks need to be able to take the extra of residents.* *The council needs to implement more accessible, reliable and affordable public mass transit to cater for the substantial residential developments to the west and north east of the city. It is not realistic to expect residents not to drive unless there is a sound alternative. The increased traffic created by these developments will have a seriously detrimental effect on existing residents which is fundamentally wrong.*
Be more ambitious	10	*1.5*	*Some of these measures might bring emissions down in the short term, however a longer term plan is needed and whilst these might be ok to bring the limits down quickly, they are not a sustainable option.* *Be braver, stop pandering to the motorist.*
Non-traffic pollution	9	*1.4*	*The increased use of wood burning fires and stoves means an increase in PM2.5 particulates. Cardiff Council needs to take action to reduce these emission which are seriously detrimental to public health.* *The council should ban fireworks as these contribute to NO2 emission. The council should ban wood burners and should also stop the pollution from the steel world and incinerators in Splott!*
Penalising drivers	6	*0.9*	*Not unless you wish to punish all car drivers* *Stop processions and demonstrations which force cars to wait engines running whilst they pass. Priority to vehicles not pedestrians on the outer circle. Decrease the vehicle pedestrian interface which slows/stops traffic leaving engines running.*

Education	5	*0.8*	*I think it is very important to publicize the restrictions / changes and why they are necessary, via the media and roadside advertising, to get drivers on side.* *All active travel and public transport infrastructure developments should be supported by a wide public information campaign. A modal shift to walking, cycling and using public transport will not be achieved unless citizens are aware of changes and how they impact on them.*
Commuting v Agile working	4	*0.6*	*More home working for employees so staff aren't having to commute to work every day, thus reducing cars on the road. Not everyone is able to use public transport or cycle etc. due to geographical issues.* *Working with major employers in the City to promote agile working, so reducing the need for people to travel into the City to work (i.e. they can work from other sites)*
Move the problem elsewhere	4	*0.6*	*Pollution will increase outside the zone as people avoid driving through the zone.* *A low emission zone in the centre will push traffic to other routes, which will just shift the pollution, rather than reduce it.*
Impact on businesses	4	*0.6*	*This will damage businesses & trade within the city centre.* *As a small business owner in CF11, I regularly end up driving around Riverside for 15 minutes looking for parking. I can't afford the daily meter rates and free parking is hard to find. CCC makes no provision for business parking and doesn't offer business permits in the Riverside area. This means many Resident only spaces left unused all day, the two hour spaces in high demand and business owners like me having to drive round in circles until a space becomes available*
Commercial vehicles	4	*0.6*	*Reduce the number of large vehicles such as HGV's from accessing the city centre during peak hours.* *Why not have HGVs stop at M4 jct 33, 32, 30 and then only have smaller vans come into city centre?*
Discourage idling	3	*0.5*	*Engine idling on the so-called 'School Run' should outlawed and radically enforced. Children are being*

			subjected to horrendous levels of avoidable pollution at schools and nurseries. Action is overdue.
Accessibility	3	*0.5*	*Disabled People's vehicles should be exempt. Evidence - Equalities Acts - reasonable amendments.*
Miscellaneous	53	*8.1*	*NO2 is clearly a major issue but there are others - the danger, as ever, is having a piecemeal approach -- ALL developments, including new business zones, for example, must have sustainability built in, designed in from the outset, not retro fitted!* *The cycle route with bollards by Lidl off Caerphilly road is shocking, it's always full of glass and can't be ridden on, complete waste of space and money. Road cleaners can't keep it clear of glass which means even less road space for cyclist and cars. Can't be used. Also no advertising of the new law to give cyclist 2 metres of space. Cycling in Cardiff is awful, and the worst culprits are Cardiff bus* *Stop running half-empty buses. New legislation needed in parliament.* *This should not be a priority Cardiff is not a big enough city to warrant this kind of expenditure*

Appendix 6 – Open-ended responses to Q13
Are there any other comments you would like to make about the Council's Air Quality Strategy and Action Plan?

A total of 572 comments were received for this question, which have been grouped into the following themes.

Please note, responses will add to more than 100% as more than one theme could be covered by a single answer

Theme	No.	%	Example Comments
Support the proposal	118	*20.6*	*You can't escape the current screams for progress in reducing emissions in today's world - I'd love for Cardiff to be at the forefront of this charge. Let's not focus on the short term, let's focus on being the benchmark city that others want to copy. Electric buses, electric taxis, more restrictions on the wider area for general motor vehicles, real investment in cycle schemes for all residents of Cardiff - I support the schemes proposed but urge you to take this opportunity to really shake things up and pioneer Cardiff as being THE GREEN CITY of the UK. Let's attract people and businesses who have a strong social responsibility - by being THE green city we'll reap the rewards. Let's make Cardiff stand-out very prominently for all of the right reasons - this is our chance!* *I'm glad steps are being taken not only for reasons of public health and wellbeing, but also as a response to climate change.* *Looks great, now get on with it. It can't come quick enough!* *I support many of the suggestions made so far, but at the same time should wish the Council to proceed with caution in order to limit any expensive mistakes, and also to gain the backing of the public and businesses.* *Pleased to know that the Council is taking action to improve air quality. The more we can do so much the better.*
Be more ambitious	91	*15.9*	*It isn't nearly enough. Why not be a leader in europe rather than catching up?*

			It's neither ambitious nor strong enough to make the kind of impact to improving air quality and reducing carbon emissions that we require. *These are small steps that won't tackle the issue. You'll still be non-compliant and I might make court action. To resolve this you have to be bold and close roads. It's quick, easy and efficient solution* *Very 1 dimensional. Need a holistic approach that includes minimising car use, cleaner cars and carbon absorption.*
Promote / Encourage / Enable Active Travel	68	*11.9*	*Introduce more rent a bikes, they have and are so successful.* *Many of the measures are welcome but there is a long way to go before it is safe and pleasant to cycle in Cardiff. Perhaps developing some of the lanes behind the terraced houses in Heath and other parts of the city as cycle paths would be an inexpensive and safe way forward* *I'd like to see how the council plans to address cycle security. Improved access has to come with a level of confidence that my bike will be there when I return from my visit to the city centre. Cycle theft it seems is an easy crime with low levels of detection.* *Make as many safe cycle routes to town and through town as possible. Many cycling commuters cannot get through the city safely*
Improve public transport	60	10.5	*I would leave my car at home and use public transport to get to work if buses were reliable, affordable and operated on better routes. While it's cheaper for me to use my car and I am assured that I can get to where I'm going after work on time (especially if that's picking up my child) because I'm using the car, unfortunately, I'll continue to use it.* *massively improve public transport before further road schemes* *A Bus Interchange would help.* *The council has to take into account the realities of life for working families. More cycle lanes will not help families with getting kids to nursery and then getting to work (outside of Cardiff) public transport is too expensive, not frequent enough, not family*

			friendly and therefore needs to be improved in every respect to get people out of cars.
Against 20mph zones/speed bumps	52	*9.1*	*One thing I'm not sure I understand is the expansion of 20mph zones. Surely slowing down traffic would increase emissions, as vehicles are on the road longer? Isn't it in the interest of air quality for motorists to get to their destinations as quickly as possible?* *Reducing vehicles to 20mph just means they are not working efficiently and are therefore a lot more polluting* *As the council is forcing citizens into their cars by removing bus services, cars need to be allowed to move more freely by removing speed bumps and traffic narrowing points.* *It is not up to date. The third most common cause of Alzheimer's Disease is caused by previously molten iron entering the brain. This can only come from disc brakes and all engines so features like traffic slowing (road humps/narrowings etc.) need to be removed*
Discourage car use	32	*5.6*	*Incentivise people not to use cars - people will do what's easiest or what benefits them the most.* *Much talk of Active travel and buses as a result of these plan...but little or no talk of reducing vehicle numbers and capacity in the city which will be crucial. Every document council publish should be indicating to people that cars will become increasingly less welcome and unnecessary in the City Centre. Publish Numbers of parking spaces in each ward with targets for reduction of space reduction over next 1, 2, 5 years - and deliver those reductions.*
Accessibility issues	30	*5.2*	*I am concerned that the proposed schemes are not suitable for people with mobility problems.* *It's all aimed at trendy green people who can ride bikes are able bodied and are fit! Most people don't fit into this category.*
Enforcement	27	*4.7*	*20mph zones are ineffective without enforcement and active measures to reduce speeds. Please stop undermining respect for law and wasting money. I support 20mph zones but they must all have enforcement and active measures.*

			Give clear instruction on rules of joint pedestrian and bike lanes, enforce the rules.
Against the proposal	25	*4.4*	*Slowing traffic & closing streets would make it worse, not better* *I don't believe that the air quality is as bad as stated. I think that the testing procedure should be checked and any instruments be calibrated by an independent authority*
Businesses / Industry / Residents	22	*3.8*	*The one thing I do not feel happy about is for businesses in the city centre to have to pay special fines if the vehicles are highly polluting. One of these days, all the businesses will have left the city centre, because it's just no longer profitable* *Would it be possible to consider existing City Centre Residents who have already had cars, such as residents at Landmark Place?*
As soon as possible / Overdue	21	*3.7*	*Please hurry up and get on with it* *It is encouraging to see proposals being made but would press for urgent action to be taken without further delay to address the current climate crisis.*
Implement / Do it / Don't get put off	21	*3.7*	*Implementation is important. Over the years the council has had many strategies which have either been not implements, or have lapsed. Progress needs to be continuous.* *Please implement these measures. There will be complaints from people who don’t see that cars kill the city, but with some vision and time (and some money) the city can be a cleaner, more pleasant place.*
Safety of pedestrians	20	*3.5*	*Cycleways are all very well but Cardiff, unlike many urban areas in the UK, doesn’t make much effort to segregate walkers and cyclists. A substantial downside to the enjoyment of open spaces here is the need to be constantly on the alert for the many cyclists who appear not to believe that pedestrians should be on their turf at all.* *Improve facilities for walking pushchairs and wheel chairs throught the active travel routes*
Utilise Nature	19	*3.3*	*More greenery, plants to absorb pollutants, green up roundabouts and pockets of land.* *The Air Quality Strategy does not make any reference to the benefits that green infrastructure*

			can have in terms of air quality. Green Infrastructure includes street trees, soft landscaping and hedges, as well as green roofs, green or living walls and green screens. The right vegetation in the right place can act as a barrier to separate pedestrians from traffic pollution, as well as trapping pollutants such as particulates and absorbing CO2. The Air Quality Strategy should seek these benefits, and further advice can be found in the Mayor Of London's 'Using Green Infrastructure to Protect People from Air Pollution'
Parking	19	*3.3*	*Parking in Cardiff is too cheap; if we want to reduce emissions, we need to increase parking costs; and massively increase enforcement of existing parking restrictions. In London a car on double yellows is towed in minutes.... in Cardiff... "Meh, whatever, not-my-job-mate" attitude gets us nowhere. Less cars = more liveable city, better wellbeing.* *Please do something about all day car-parking in suburb streets with people using train for city centre work/shopping- pushing pollution and traffic disruption just further out from city centre. This also needs to be tackled with permit parking only zones around Heath Hospital.*
Stop building houses / ensure infrastructure	18	*3.1*	*Ill-considered knee jerk response lacking proper thought or a proper investment strategy. CCC has permitted uncontrolled development of housing without having due regard to the impacts. Travel infrastructure should have preceded the house building. An epic fail on the part of CCC and one that so many voices warned of.* *Ignoring the elephant in the room, of the council's huge expansion of the city housing. Resulting in more traffic and more pollution.*
School Traffic Concerns	16	*2.8*	*air quality ids not just for the city centre outer areas are just as bad ...areas around schools should be traffic free strictly i.e. a minimum mile round each school traffic free , children have legs and should be encouraged to walk a mile to and from school each day....parents who continue to pick up their sprogs should be issued with pollution fines especially for those who park in bus turning areas* *Please look into air quality outside schools.*

Increase capacity for public transport	15	*2.6*	*The council should be looking at travel over Cardiff as a whole, as the capital city with many businesses moving to the city centre public transport will be unable to cope. Our current local train line cannot cope with the number of passengers already, so to reduce access to the city centre does not make sense if the people cannot get into work reliably, and this may mean businesses will look elsewhere for a location.* *Needs more buses, need to encourage a modal shift for those who want to come into or through the City Centre.*
Longer term approach needed	15	*2.6*	*Too much of a focus on a short term fix suggests that the longer term repercussions are not really being considered, and any solution to NO2 issues in the city will be more costly in the long run due to multiple short term interventions rather than a longer term strategy.* *I am pleased to see that there is a strategy and these measures are being taken. I would encourage the council to take a bold, long term view rather than settle for measures that only answer the here and now. This is an important investment in the future.*
Move the problem elsewhere	15	*2.6*	*Thought should be given to the areas just outside a clean air zone. We do not want extra traffic building up, looking for non-existent parking or creating unsuitable rat runs to avoid the area.* *Less emphasis needs to be put on the city centre a lot of which is pedestrianised and more effort around the city where people live and children walk to school.*
Metro / Trams / Alternative transport	15	*2.6*	*South Wales Metro needs to be implemented ASAP especially in light of all the new house building in and around the city. The rail services are not fit for purpose* *Bring in trams to the city centre. Those trams can take punters to bus stops outside the city centre when buses can go to the required destinations.*
Against Congestion Charge	14	*2.4*	*Definitely no charging areas - they do nothing to help clean the air, but still incur costs of implementation. The privileged rich who can afford the charges, would carry on with their driving*

			habits, but all Cardiff Council tax payers would have to foot the cost of the wages of staff employed to deal with the paperwork (or online running) needed to implement this charge. Pollution will continue. *Please don't introduce congestion charges or similar as it will harm trade*
Traffic flow	13	*2.3*	*Introduce smart control of traffic lights to minimise standstill time for vehicles which makes for less pollution and faster journeys.* *Get the traffic moving, not make it more congested so there is more pollution. There are a number of traffic calming measures that hold the traffic up, so the cars are at a standstill causing more pollution.*
Education / Increase awareness	11	*1.9*	*Increase public awareness of these issues.* *Is there a way to publish or put on boards the air quality levels? It may make people consider their driving habits if they can see how bad it is. Could it also be equated to air quality that people understand? E.g. today's air quality is the equivalent of 10 garden bonfires etc.*
Non-traffic pollution	10	*1.7*	*1) No mention of heavy industry such as the steel works. 2) No reference to emissions from hotels / businesses in the City. 3) Overall energy usage should be considered For example all shop front advertising signs turned off by midnight.* *How about people with solid fuel fires? You can't breathe in my area during winter because of the stench. Also carcinogenic. More important that the City Centre.*
Consultation Process	10	*1.7*	*Public consultation event only available on Saturdays, there should be weekday times so that those parties working in the city centre can WALK to the event not travel on a weekend.* *Good to see that there is some activity but it has been largely the same over the last 5 or 6 years. I appreciate that austerity does not help, but I have been asked in loads of your surveys in the past whether I support the 20mph limit across the city -- stop asking: either people are in favour then implement or they are not, then think of something else. Clear long-term strategy is needed and it needs to be clearly communicated.*

Cheaper public transport	9	*1.6*	*Bus travel is too expensive esp. for those having to commute from outside the city (Vale of glam) Public transport between authorities needs to be more joined up.* *Make bus travel more appealing - don't bother with Wi-Fi and charging points - this isn't what's needed - focus on affordability/simplicity/transfer options. To do school run and work commute on buses would cost me >£13 a day - not realistic and people will opt for using the car.*
More Charging points	9	*1.6*	*More electrical charging outlets, perhaps in city centre car parks. Investment is this would be preferred over grants to taxis.* *How do you propose that people living in terraced housing charge their cars?*
More info needed	8	*1.4*	*Are there any legal time limits to achieving a clean air city?* *Do changes to the roads really cost 10x more than replacing the oldest buses with electric ones??*
More vehicles to be ULE	8	*1.4*	*Replace the pool car fleet with electric vehicles or hybrids and lead by example* *All public transport should be emission free*
Traffic flow	8	*1.4*	*The council continues to increase pollution and congestion by installing speed humps and road narrowings. It should think scientifically instead of like a religious cult. Aim to facilitate smooth traffic flow, not impede it at every opportunity.* *Not properly thought through. Need free-flowing bypass for cross city traffic*
Anti-car	8	*1.4*	*Generally this is completely anti car, and must be stopped at all costs. You have a duty to all city residents, including car owners, and the council must lose its anti-Car bias.* *Appears, as usual prejudiced against drivers whilst not providing any improvements to infrastructure. If council wanting to improve clean air why build thousands of new houses on green belt sites!!!*
For congestion charge	6	*1.0*	*You can reduce the volume of vehicles by adopting a standard congestion charge across the inner city* *I'm not sure why creating a 'charging zone' for polluting vehicles is not part of the action plan*

Ban idling	6	*1.0*	*No mention is made of measures to enforce existing bans on stationary and lay-over vehicles continuing to run the engine.* *As in many other countries, traffic signals should be equipped with simple, large-format digital displays showing drivers how long until the lights turn green (called: TTG Time-Till-Go). This gives the informed driver the opportunity to switch off the engine until needed. Again, this is a self-funding investment as all fuel, emissions, human health and life savings will repay the costs in less than 6 months (evidenced abroad)!*
Not just city centre	5	*0.9*	*City centre focussed schemes do not address Cardiff wide air quality issues. Also - Cardiff city council needs to have more, better placed, air quality monitoring stations. Two is not adequate over such a large area- currently the Queen Street station is stuck inside a construction site so cannot collect any meaningful data.* *The quality of air in Splott is appalling.*
Involve youth	3	*0.5*	*In my experience once you have the youth on board with this (especially as they have been protesting) you could set up school ambassadors , I know that they will then take this information home to the families and it's a start of a good drip-drip communication, especially high schools and universities*
Park & Ride	3	*0.5*	*Increase provision for Park and Ride to encourage motorists to leave their cars on the city outskirts*
Miscellaneous	56	*9.8*	*How about a ban on old Ice cream vans which keep their non-Euro compliant diesel engines running all day especially near playgrounds.* *The litter here contributes to pollution too, fly tipping is terrible here* *Fill in the potholes correctly before using money on air quality functions.* *Train infrastructure should be considered too, old diesel engines need to be replaced asap with electric lines and trains idling at stations for upwards of 5 minutes needs to be stopped. I use trains a lot and am often coughing and choking at stations due to the fumes.*

	Develop the River Taff as a major transport thoroughfare.

Cardiff Clean Air Zone Study - Economic Appraisal Methodology Report

Report for Cardiff City Council

ED 11182 | Issue Number 1.3 | Date 03/06/2019

Customer:

Cardiff City Council

Customer reference:

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Ricardo Energy & Environment reference:

Ref: ED11182- Issue Number 1.3

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1 Introduction

City of Cardiff Council (CCC) has been directed by the Welsh Government to carry out a Nitrogen Dioxide (NO_2) Feasibility Study for non-compliance with the NO_2 limit values. This report sets out the economics assessment, focused on Cost Benefit Analysis (CBA), of the CASAP (Clean Air Strategy Action Plan) Feasibility Option in Cardiff. The scope of options considered covers[1]:

- *The 2016 baseline*: as the counterfactual against which to compare the mitigation options;
- *A Clean Air Strategy Action Plan designed for the Final Business Case (FBC CASAP):* package of measures to reduce transport emissions across Cardiff;
- *A Charging Clean Air Zone (CAZ)* – targeting cars in the central area.

The Joint Air Quality Unit (JAQU) have provided detailed guidance regarding the economic appraisal of mitigation options. This provides a steer for many of the key data inputs and assumptions that have framed how the analysis is undertaken. The key guidance documents include:

- Options Appraisal – Guidance (2018)[2] (and preceding versions of this guidance)
- National data inputs for Local Economic Models (2018)[3].

We base our analysis on this guidance as well as using TUBA (Transport Users Benefit Analysis), the Propensity to Cycle Tool[4] (PCT) and the Active Travel Toolkit as per Department for Transport (DfT) WebTAG Unit A5-1[5] to perform analysis of the transport impacts in accordance with transport appraisal guidance.

The analysis is underpinned by the following general assumptions:

- Each impact is assessed relative to a 'do minimum' counterfactual
- All impacts are presented in real terms with a Price Year of 2018.
- All impacts are discounted to 2018 applying Green Book discount factor of 3.5%.

[1] During the Outline Business Case (OBC) phase, two CAZ options were considered and ruled out after evaluation. CAZ 1 applied a charge on private cars and CAZ 2 on HGVs.
[2] Unpublished – provided directly by JAQU to cities
[3] Unpublished – provided directly by JAQU to cities
[4] https://www.pct.bike/
[5] Active Mode Appraisal (May 2018)

2 Definition of modelling option scenarios

2.1 Setting out the options

The analysis is defined by the options that are included in the Final Business Case (FBC). These options include a refined package of measures to reduce emissions covering all key transport modes in the city: cars, freight, buses and taxis. This introduces a series of measures previously assessed in three unique CASAP phases. These phases have been reviewed and a final package comprising key elements of these phases (FBC CASAP) has been taken forward in the air quality modelling and economic assessment for the FBC. This has been considered as an alternative to a baseline scenario for achieving compliance with the NO_2 annual mean air quality directive in the shortest time possible. Two variations of charging clean air zones were also considered during the Outline Business Case (OBC), CAZ 1 where charges apply to private cars and CAZ 2 where charges apply to light goods vehicles (LGVs) and heavy goods vehicles (HGVs). Both options were assessed for the OBC but at this stage only the CAZ 1 option has been assessed as this had the greatest impact on the compliance area of concern on Castle Street. The details of options assessed for the CBA are set out in Table 1.

Table 1 – Shortlist for assessment

Scenario	Measures reflected in air quality modelling
Baseline 2021	Expected changes to population, employment and the highway/public transport networks.
FBC CASAP	**1. Bus retrofit Package: 80 % of buses upgrade to Euro 6** **2. Taxi Licensing: Euro 6 for new licensees and upgrade incentives, with some upgrading to PHEV/EVs;** **3. Electric Buses on service routes 27, 49/50 and 44/45;** **4. City Centre Schemes** a. East Side Scheme b. Westgate Street Scheme c. City Centre North Scheme **5. Cycling Programme to end of 2020 (Cycle Scheme 1);** 6. **Active Travel Package (2 mph zone for walking and cycling)** Note: Measure 5 and 6 were modelled together in the AQ and Transport models. We present them separately for clarification when reporting implementation costs.
CAZ 1	**1. No CASAP measures included;** **2. £10 charge for private cars entering city centre charging clean air zone**

2.2 Models developed

We have designed our approach to be consistent with HMT's Green Book guidance for appraisal. We draw on guidance provided by the JAQU to inform the assessment in accordance with Department for Transport's A.1 range of transport appraisal guidance.

The approach to assessing the impacts associated with upgrading vehicles (and associated OPEX, fuel and CO_2 impacts) and air quality impacts has been tested in multiple CAZ cities. Congestion, implementation costs, welfare, OPEX and fuel CO_2 impacts associated with additional distances driven are more commonly assessed using TUBA. TUBA is deployed because as part of this appraisal we are considering a number of transport schemes (as part of the CASAP) which are more commonly assessed using this approach. The Propensity to Cycle Tool and Active Mode Appraisal Toolkit have been used to determine the current cycle and walking demand and forecast potential future year cycle usage for the Active Travel Package and evaluate their benefits. The results of TUBA modelling, Ricardo's economic model and the Active Mode Appraisal Toolkit are combined in calculating overall NPV.

Table 2 – Economic models used

Option	Modelling Effort
FBC CASAP	Ricardo's economic model is used to calculate vehicle upgrade costs for the bus and taxi measures (and associated OPEX, fuel and CO_2 impacts) and damage costs associated with aggregate reductions in pollutants. It is also used to calculate the monetary impact of a change in NOx and PM2.5 emissions. CCC information used for implementation costs. Use of TUBA which provides an estimate of the economic benefits associated with congestion impacts, vehicle operating costs (OPEX, fuel) and greenhouse gas emissions. Use of the DfT Active Mode Appraisal Toolkit to appraise potential scheme benefits from the Active Travel Package.
CAZ 1	Ricardo's CAZ economics model has been used to calculate the total upgrade costs associated with the introduction of a charging scheme (and the associated vehicle costs including fuel, CO2 and OPEX). It is also used to calculate the monetary impact of a change in NOx and PM2.5 emissions and the implementation cost associated with setting up the scheme. TUBA is used to assess the impacts resulting from changes in congestion (travel time) and the welfare impact.

The following sections define the response (or take-up) of individuals and businesses to the two options considered in the economic modelling. These critical assumptions determine the number of vehicles affected by each option considered and the associated impacts. Specific modelling assumptions and data inputs are provided in the Appendix of this document.

2.3 FBC CASAP Assumptions

Measures accounted for in the economic modelling are:

- Taxi Licensing (Euro 6 for new licensees), with a percentage upgrading to EVs/PHEV;
- Electric buses on service routes 27, 49/50 and 44/4;
- Active Travel Package;
- Cycling Programme to end of 2020 (Cycle Way 1);
- City centre improvement schemes comprising Westgate Street Scheme, East Side Scheme and City Centre North (Castle Street) Scheme;
- Bus retrofit Package: Retrofitting Scheme of Cardiff City Buses and other private operators (805 of the total fleet)

2.3.1 Zero Emission Buses (ZEB)

The ZEB measure will implement 36 electric buses on a number of routes within the City Centre. These would replace the oldest vehicles in the fleet and so the remaining fleet would consequently have a newer profile. There are 3 service routes which are being targeted with ZEB buses; 27, 49/50 and 44/45. Data was provided by the traffic modelling, based on data from June 2018 and extrapolated to baseline year (2021).

2.3.1.1 General assumptions (traffic and air quality modelling)

The air quality modelling exercise only focuses upon dispersion modelling of NO_2. As such an electric bus produces zero NO_2 emission and so a fleet penetration percentage for the ZEB has been calculated to reduce bus traffic flows. In the transport modelling the ZEB reductions were applied to the routes on which the buses operated, and it is assumed that every service contributes an equal number of bus traffic flows along the route and so the ZEB reduction is only applied in proportion to the ZEB services along that route[6].

The introduction of ZEBs will allow the older buses to be phased out. CCC provided Ricardo with the Euro standard details of Cardiff City Bus's fleet. This enabled the % of compliant buses to be calculated for Cardiff City Bus before the introduction of ZEB. CCC intend to replace 36 Euro 3 buses with ZEBs. Consequently, the effects of fleet turnover upon the % of compliant buses was calculated and used in the model.

2.3.1.2 Economic modelling

We assume the introduction of ZEBs to take place in 2021 and replace the 36 Euro 3 buses. It is also assumed that these buses would have no residual value and would be scrapped. The ZEB upgrade and implementation costs are then calculated as follows:

- Upgrade cost:
    - £ 362,666 per ultra-low emission bus (CCC, 2018)
    - We then calculate the marginal cost of a new vehicle: electric vs Euro 6 diesel (Source: Ricardo Fleet Projection Tool, 2018).
- Implementation costs:
    - £ 455,000 (CCC, 2018£) covering 45 charge points at £ 10,080 per point, BYD Charging Management System and set-up costs (one-time, including commissioning of the system and training)). This does not include supply/ connection costs
    - In addition, a 36% uplift on any implementation costs has been applied as optimism bias.
- Fuel efficiency:
    - Diesel switch (litres/year) to electricity (kWh/year).
    - Energy consumption 0.3 kWh per km, 2011 (WebTag, 2018).
- Fuel prices: Electric Central Domestic p/kWh (WebTag, 2018).
- OPEX: £/annum 7,784[7]. Assume maintenance costs reduce by 33% every 10 years[8] (based on Ricardo Study for TfL, 2014).
- CO2 emissions: Electricity emissions factors to 2021, total consumption 81,304 kWH/year; giving 22,168 KgCO2/annum[9].
- Replacement costs: no data on how much cheaper a BEV bus can become in 10 years' time. Assumed the ratio for Taxi BEVs now. No 'margin' is applied as the data for Bus BEV is expected retail.

2.3.2 Taxi Licensing

Information on private hire vehicles and hackneys registered with City of Cardiff Council was provided by the Council. In addition, the ANPR data to produce Euro standards for the taxi fleet mix. Since the Euro standards defined by the ANPR dataset and from CCC's taxi licensing result in a different Euro standard composition (one is based on trips and the other vehicle numbers) a % shift approach was used to assess the impact of the licencing change. The taxi information included the number of taxis which fall into 3 age categories; 10 years or older, between 10 and 4 years old and under 4 years old of registered taxis. This was used to determine the current % of the taxi fleet naturally compliant. It has been assumed that all vehicles which are older than 10 years will register a new taxi under 5 years old. Hackney assume an uptake of 5%; which gives a number of EVs/PHEV of 20.5; thus having 2% in fleet. Private hires assume an uptake of 20%; which gives a number of EVs/PHEV of 42.2; thus having 3% in fleet.

Moreover, the model assumes that, for Taxis that upgrade in an electric vehicle or a PHEV, would not do without incentive. It is assumed that without the CASAP policy scheme, when vehicles reach the end of their life, the owner will purchase a Euro 6, not an Electric/PHEV vehicle. the this impact is felt longer

[6] This generates the % reduction in bus traffic flows assumed for roads used by ZEB targeted services is as follows: 27: a 20% reduction in bus traffic flows; 44/45: a 14% reduction in bus traffic flows; and 49/50: a 14% reduction in bus traffic flows.
[7] Note that the 7784 is based on the 10.000 figure of Fuel Cell maintenance (page 55 of the linked report). It has been interpolated between 10.000 (2010 value) and 6.666 (2020 value). The page 54 of the report contains a different figure (6610 for double decker bus). If we use the same 'reduction factor' of 33%, then that would be 6610 (2010) and around 4400 (2020), and the real figure is somewhere in between (around 5000 something would guess). Source: http://www.lowcvp.org.uk/assets/reports/LowCVP-Ricardo%20Bus%20Roadmap%20FINAL.PDF
[8] Source: Ricardo study for TfL (2014): 'Environmental Support to the Development of a London Low Emission Vehicle Roadmap' (unpublished)
[9] Based on kgCO2e/kWh, long-run marginal (WebTag, 2018).

than the other impacts, which cease two years after the scheme is implemented, for EVs, the benefit occurs for longer in to the future as it is as the EV (fuel used, OPEX and CO2) outperforms an Euro VI

This results in a 45% increase in the number of compliant taxis for Hackneys and 16.5% for Private hire. This was used as an adjustment factor to shift the non-compliant (i.e. non-Euro 6) taxi traffic flows (AADT) to compliant taxi traffic flows (AADT) for all roads in the study area which has been used in the air quality modelling.

The marginal cost of these vehicles upgrading to Euro 6 early has then been used within the economic assessment. At the time when this study was made, the CCC targeted 620 vehicles which following the change in policy will be required to change to Euro 6. Their intention is to contribute £1000 each year over 3 years period for the running costs (not purchase) of the vehicles which would equate to a total cost £3000 per vehicle, with a total cost of £1,860,000 of public funding. However, while the funding influences who pays the cost of upgrading the required taxis, the overall cost remains the same, this is reflected in the model.

Table 3 – Taxi fleet for different scenarios

	2021 Baseline		FBC CASAP	
Hackney fleet	Number	%	Number	%
9-10 years or older	410	45.50%		0.00%
Between 10 and 4 years old	432	47.95%	432	47.95%
Under 4 years old (i.e. Euro 6)	59	6.55%	469	52.05%
Assumptions: Hackney % uptake: 5%; number of Evs/PHEV: 20.5; % in fleet: 2%				
Non-compliant	842	93.14%	432	47.79%
Compliant	59	6.53%	469	51.88%
Private hire	Number	%	Number	%
10 years or older	212	15.81%	0	0.00%
Between 10 and 4 years old	738	55.03%	738	55.03%
Under 4 years old (i.e. Euro 6)	391	29.16%	603	44.97%
Assumptions: Private hire % uptake: 20%; number of Evs/PHEV: 42.4; % in fleet: 3%				
Non-compliant				
Compliant				
Total Non-complaint	950	74.33%	738	57.75%
Total Complaint	391	30.59%	603	47.18%

2.3.3 Bus retrofit Package

After the introduction of the ZEBs 80% of non-Euro VI diesel buses are retrofitted to Euro VI. The economic assessment assumes the following costs

- Implementation costs (telematics and data report for 5 years): £150,400;
- Retrofitting cost: £15,000 per unit of retrofitted bus;
- Total buses retrofitted: 150;
- Total upgrading costs: £2,250,000
- OPEX: E6 proxy value for upgraded buses

Error! Reference source not found. shows the bus fleet distribution for the different scenarios.

Table 4 – Bus fleet for different scenarios

	2021 Baseline		FBC CASAP	
Cardiff Council	Number	%	Number	%
Euro 3	95	27%	0	0%
Euro 4	44	19%	27	12%
Euro 5	50	22%	50	22%
Euro 6	40	17%	119	52%
Electric	33	14%	33	14%
Non-compliant	156	68%	77	34%
Compliant	73	59%	152	66%
Other bus operators	Number	%	Number	%
Euro 3	4	4.90	0	0%
Euro 5	57	70.40	0	%
Euro 6	20	20.70	81	100%
Non-compliant	61	75%	0	0%
Compliant	20	25%	81	100%
Total Non-complaint	217	70%	77	25%
Total Complaint	93	30%	233	75%

2.3.4 Active travel Package and Cycle scheme (CS 1)

The package comprises 20mph zones and cycle scheme CS1 (Heath to City centre corridor) measures rolled out in two areas of the city, which assume a 3.5% reduction in car driver mode share and applied in the transport model trips with both origins and destinations in the given areas.

Active travel package measures were modelled using the Propensity to Cycle Tool[10] (PCT) to determine the current cycle and walking demand and forecast potential future year cycle usage. The PCT has been developed, using Department for Transport and Welsh Government funding, to assist transport planners and policy makers to prioritise investments and interventions to promote cycling. Using the 2011 Census 'Journey to Work' data, the tool estimates levels of active travel commuting on a significant number of roads and cycle routes throughout the country. The tool utilises several assumptions based upon a variety of policy interventions, using evidence from the UK and elsewhere in Europe. For the purposes of this assessment, the PCT 'Go Dutch' scenario has been used as this assumes levels of cycling akin to those achieved in the Netherlands. It is anticipated that the high-quality infrastructure proposed for the cycleways as well as the wider cycleway network proposed for Cardiff, has the potential to facilitate a network of quality equivalent to that available in the Netherlands.

The PCT does not estimate future levels of walking. AECOM have reviewed the results of the 2017 Cardiff Active Travel Survey[11] to establish whether commuting walking levels have grown since 2011 and found a negligible change in walking levels. Therefore, no growth in walking has been assumed as part of this appraisal. In addition, the forecasts also do not consider the impacts of the additional network and land use developments, or non-commuter journeys. The forecast usage levels can therefore be considered as potentially conservative estimates of potential usage.

The total projected cost is forecasted at £1,400,000 for 20mph to encourage walking and cycling and £5,800,000 for cycling measures (Cycle Way 1) (Source: CCC).

[10] https://www.pct.bike/
[11] https://www.cardiff.gov.uk/ENG/Your-Council/Have-your-say/Ask%20Cardiff%20Library/Transport%20Survey%202017%20Report.pdf

2.3.5 City Centre Schemes

The main purpose of these schemes is to allow for better and more efficient movement of public transport (buses) and increase active travel capacity in the City Centre. Such schemes also look to reduce highways capacity for private vehicles which is intended to be a catalyst for increased modal shift to public and active travel. All three elements of the City Centre Schemes have been included in the assessment.

Westgate Street Scheme

The main aim of this scheme is to accommodate the new Transport Interchange and Central Square Development, whilst also Improving Air Quality within the City Centre AQMA. This will be achieved through removing through-traffic from Westgate Street using a bas gate (which also allows taxi access), implementation of North - South cycle ways and dedicate cycle lanes around Central Square. In addition, the scheme will offer improved safety for pedestrians via improved pedestrian crossing facilities, 20mph speed limits and an improvement to the pedestrian environment outside of the national stadium.. Through-movements were prevented from using Westgate Street by closing the link. Access for car trips to all city centre model zones has been maintained, although trips may need to re-route to avoid the closure.

East side scheme

The main aim of this scheme is to provide a new dynamic for the bus network modelled through movement prevented on Churchill Way, except for buses, and applied in transport model.

City Centre North Scheme

The main aim of this scheme is to provide a new dynamic for the bus network modelled with removal of vehicle lane and replacement with a cycle lane. The scheme will also remove one eastbound lane to create the dedicated two way cycle way on Castle Street and the Taff Trail routes

The FBC CASAP now assume exceptions for taxis (not included in CASAP 1-3 modelling) for Westgate and East side measures. The implementation of all three schemes (City Centre Schemes) include surveys/ modelling, design, accommodation works, construction, project management, monitoring and evaluation, and promotion, having a total expenditure forecasted of £22,252,000 (CCC, 2019) (see Appendix 1 for further details).

2.3.6 Budget allocated

A summary of all the costs forecasted by Cardiff City Council for each CASAP measure was provided by the Clean Air Cardiff Department and shown below in **Error! Reference source not found.**. Note that not all of these are included in the economic appraisal (see section 5.2.4 **Error! Reference source not found.** for further details).

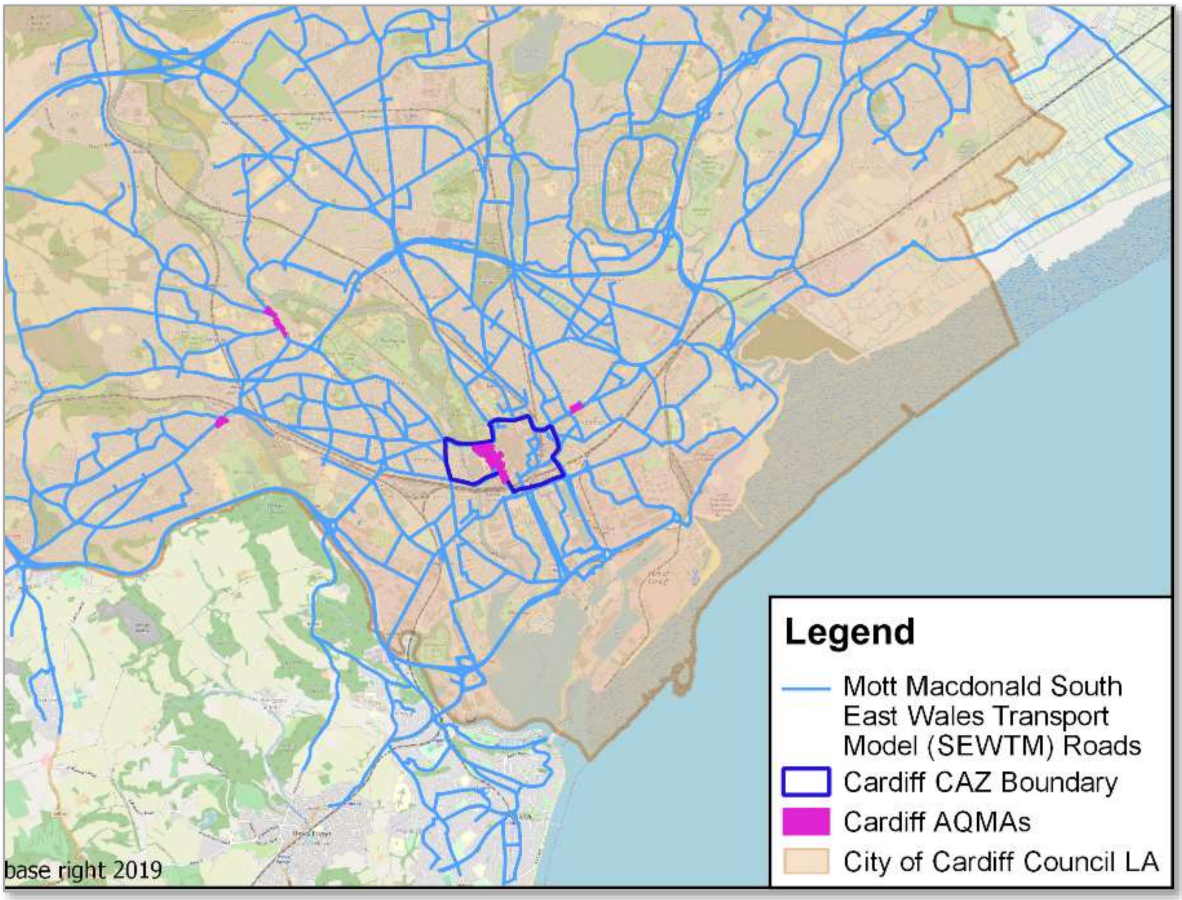
Table 5 – CASAP 3 Implementation costs (£2018), from CCC

Our assumption	2018	2019	2020	2021	2022	TOTAL
CCC	Pre 2019	2019/2020	2020/2021	2021/2022	2022/2023	TOTAL
ZEB		£455,000				£455,000
Bus retrofit		£2,250,000				£2,250,000
Taxi Licensing		£620,000	£620,000	£620,000		£1,860,000
Active Travel Package		£1,468,000				£1,468,000
Cycle Way 1	£107,000	£1,464,000	£4,297,000			£5,868,000
Cicty Centre Schemes	£950,000	£4,245,000	£10,163,000	£3,481,000	£3,413,000	£22,252,000
TOTAL	£1,057,000	£10,502,000	£15,080,000	£4,101,000	£3,413,000	£34,153,000

2.4 CAZ 1

This is a charging clean air zone which encompasses the inner-city centre (see **Error! Reference source not found.**). The majority of the upgrade assumption recommended by JAQU have been outlined within the transport modelling report. Note that based on the requirements from CCC a £10 charge for private cars entering city centre charging clean air zone is assumed.

Figure 1 - Map of CAZ boundary, AQMAs and Mott Macdonald's sub-regional transport model links



Clean Air Zone (CAZ) is a charging zone covering Cardiff City Centre and bordered by the following roads, A4119, A4160 and the A4161 the area includes the main Cardiff train station as well as many key attractions including the Principality Stadium and the main shopping area. The charging zone would require all non-compliant vehicles to pay a charge to enter the zone. For CAZ 1 all private cars are required to pay £10 per day to enter the CAZ zone. The charge of £10 associated with CAZ 1 applies to cars only and the behavioural response in relation to this charge has been based upon a JAQU default response data (taken from modelled responses to the London ULEZ). JAQU assumptions are based on a £12.50 charge as such, the behavioural responses associated with the charge have been linearly scaled down to reflect how the population would behave in response to a £10 charge. The traffic model outputs generated, and used in the air quality modelling, then take account of re-distribution of traffic and the affect upon proportions of compliant/non-compliant vehicles.

Both the CAZ and the CASAP analysis follows a Cost Benefit Analysis methodology which attempts to assign an economic value to all the impacts associated with the measures, taken across a 10-year period and then discounted to produce a Net Present Value. The impacts associated with the CAZ are described in the following section (3. Scope of impacts assessed).

With regards to the split of petrol vs diesel it is assumed that the mix of compliant and non-compliant petrol/diesel euro standards are the same before and after the CAZ. To elaborate on this, there is no upgrade assumption to a specific euro standard only that the vehicle is compliant.

3 Scope of impacts assessed

Any scheme to tackle air quality will impact different parts of the environment, economy and society. The economic analysis seeks to quantify and value as many of these impacts as possible given the time, resource and modelling methodologies available.

JAQU's guidance sets the basis for the scope of impacts to be assessed for a Charging Scheme appraisal. We have adopted the same approach to the CASAP measures although some of the impacts may not be relevant. In some cases, we have grouped impacts by the methodology taken to appraise them and hence may in places refer to different impacts using different terminology to that set out in the JAQU guidance.

The scope of impacts captured by the CBA, and their correspondence to the impact categories described in the JAQU guidance, are presented in **Error! Reference source not found.**.

All responses to the options are assumed to occur in 2021 for simplicity. In practice, these upgrades (and their associated impacts) could occur before or after the implementation of the options.

Table 6 - Impact description and mapping

Impact name	Description	JAQU reference
Upgrade costs	The impact on those vehicles owners that respond to Charging Scheme. These are the upfront costs for vehicle owners associated with switching from a non-compliant to a compliant vehicle. This encompasses the vehicle scrappage cost and the consumer welfare impact as described in the JAQU guidance. These will not be considered as part of the CASAP Packages Scheme.	'Vehicle scrappage costs' and 'Consumer welfare impact' for 'upgrade vehicle response'
Operating cost impacts	Those savings or additional costs that can result from Charging Scheme or CASAP Packages Measure. This includes both changes in fuel consumption and the associated cost and change in operating and maintenance costs. This can come about through additional distances travelled (handled by TUBA) or change in vehicle type (handled by REE model).	'Fuel switch costs'
Implementation costs (Investment and Operating Costs)	Cost of upfront and ongoing activity and assets required to implement, monitor and enforce the Charging Scheme, and CASAP Packages measure by the administering authority.	'Government costs'
Air quality emissions	The impact on affected populations by a change in NOx and PM emissions as a result of Charging Scheme and CASAP Package implementation	'Health and environmental impact'
Greenhouse Gas impacts	The impact on affected populations by a change in greenhouse gas emissions that result from Charging Scheme and CASAP Packages measure implementation. This can come about through additional distances travelled or change in vehicle type.	'Greenhouse Gas impacts'
Travel Time	The impact of the Charging Schemes and CASAP Package measure on traffic flow and the subsequent impact on travel time experienced by affected populations.	'Traffic flow impact'
User Charges	The cost to road users from paying the CAZ charges. This category includes for impact on consumer welfare associated with the user not being able to take their first preference. E.g. in the case of 'cancelled' journeys, the vehicle user will not be able to undertake the activity planned at the destination (e.g. shopping trip to city centre). The vehicle user will miss out on the happiness / value that they would have gained from that trip, which is captured by this impact category.	'Consumer welfare impact'

User Charge Revenues	The revenue generated through charging the non-compliant cars to travel through the CAZ. This should have no net impact on the model.	'Government costs'
Indirect Tax Revenues	The impact on revenues generated by the VAT, excises and duties levied on goods and services. This should have no net impact on the model.	'Government costs'
Walking and Cycling	The incentive to use non-motorised transport modes when an Active Travel package is implemented (cycling and walking) has a benefit on the affected population in the following ways: congestion benefit, change in the number of accidents, better local air quality, changes in noise levels, reduction of Greenhouse gases, potential reduced risk of premature death, absenteeism, journey Ambience and indirect taxation. To avoid double counting, our model includes only the following impacts: Accidents, Noise, Reduced risk of premature death, Absenteeism, Journey Ambience.	'Health and environmental impact'

Modelling has been split between TUBA, the Active Modes Appriasiall Toolkit and Ricardo's economic models as it is shown in **Error! Reference source not found.**.

Table 7 – Allocation of impact categories

Impacts	CASAP 3	Charging Schemes CAZ 1
Upgrade costs	✓ - REE Economic Model	✓ - REE Economic Model
Implementation	✓ - REE Economic Model (based on CCC data)	✓ - REE Economic Model (based on CCC data)
Welfare loss (rule of half) (Cost changes for altered trips)	✓ - TUBA	✓ - TUBA
Air quality	✓ - REE Economic Model	✓ - REE Economic Model
Time (Cost changes for unaltered trips)	✓ - TUBA	✓- TUBA
OPEX/Fuel/CO2 (distance)	✓ - TUBA	✓ -TUBA
OPEX/Fuel/CO2 (upgrades)	✓ - REE Economic Model	✓ - REE Economic Model
User Charge Revenues/ Indirect Tax Revenues	✓ -TUBA	✓ -TUBA
Walking and Cycling	✓ - Active Modes Appraisal Toolkit	-

TUBA presents a value for indirect taxation. This is because of the market price unit of account that is used in TUBA. It reflects the relevant indirect taxes paid by different user groups and accrues to public finances. The Ricardo CAZ model adopts the social approach to the CBA which means all costs exclude VAT and therefore no indirect taxation line. However, this is netted off within the TUBA outputs.

4 Developing the fleet baseline

4.1 CASAP measures

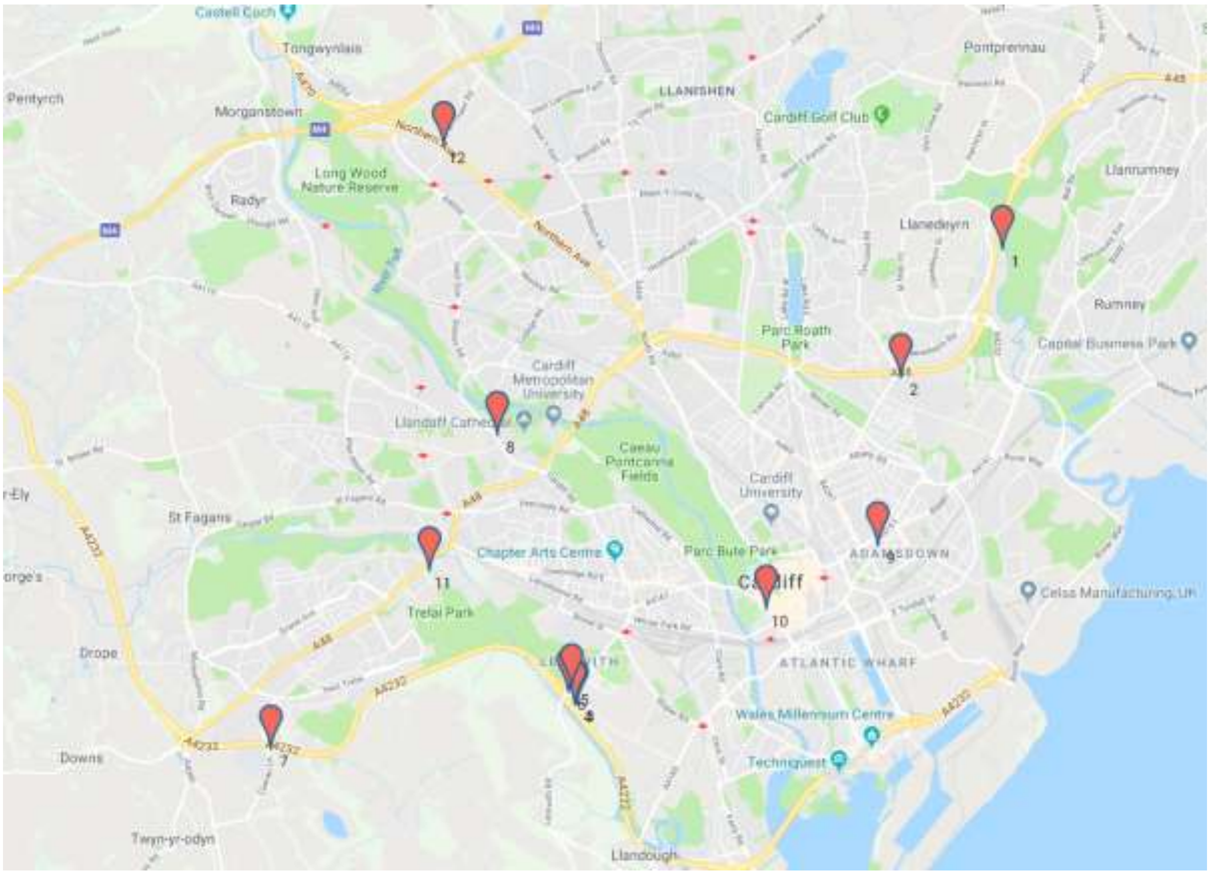
The only detailed fleet data that was required for assessment of the CASAP measures was for the ZEB, ULEB (bus retrofit) and taxi measures. The fleet data used for assessing these measures was taken directly from bus fleet and taxi fleet data held by the city Council. In addition to the information provided by the council, determination of the fuel split of Private Hire Vehicles is based on information gather through Automatic Number Plate Recognition (discussed further below).

4.2 CAZ

Fleet data was provided through Automatic Number Plate Recognition cameras which captured information on vehicles travelling in to Cardiff City Centre between 2nd – 9th May 2018 (excluding Monday 7th due to a bank holiday). All vehicles were allocated a unique vehicle registration number (VRN) as well as registering the type of vehicle: HGV (OGV1 and OGV2), LGV, Car/Taxi. The Euro type of the vehicle was also determined as well as the fuel type.

Twenty-one unique cameras were used to record the traffic travelling in to the city over the period assessed, over nine separate locations (see **Error! Reference source not found.Error! Reference source not found.**). The cameras were placed on key road links that feed the city centre, however it was recognised that not all vehicles captured on the ANPR cameras would enter the defined charging zone. This fact was considered when the uplift from our week count to annual unique vehicle count was applied. The euro standard and fuel split captured by the ANPR cameras were used to inform the baseline delineation for future assessment, however an internal Ricardo Fleet Projection Tool was applied to account for the natural turnover in vehicles that was expected to occur between May 2018 and the introduction of the scheme in 2021.

Figure 2: Locations of ANPR measurement sites across Cardiff



The following uplift factors were applied then applied to the ANPR data to reflect the expected fleet in 2021.

- Annual uplift: The ANPR cameras recorded traffic movements over a week period, an uplift was then applied to estimate the number of unique vehicles that would enter the city centre over an entire year
- Growth factor: A further uplift was used to estimate growth total growth in the fleet size between 2018 and 2021.
- Baseline turnover factor: The Ricardo Fleet Projection Tool was used to estimate how the baseline would change between 2018 and 2021 as older vehicles are scrapped and replaced with newer ones.

5 Approach to assessing the impacts

5.1 TUBA

The transport model was only run for a single forecast year (2021). TUBA is set up to accept two years as inputs in order to interpolate/extrapolate benefits across the entire appraisal period, and hence will not accept data from a single modelled year to produce a multi-year benefit appraisal. It will, however, accept single year inputs to produce an appraisal for a single year. Therefore, to account for the entire appraisal period of 2021-2030 (inclusive), factors have been calculated to apply to single-year benefits, based upon WebTAG Unit A1.1: Cost Benefit Analysis (the methods described in this unit are the same as those employed within the software). These factors incorporate the effects of:

- Time-related discounting;
- Changing values of time (for VoT-related benefits only); and
- Demand growth.

As a check of this process, TUBA has been run with the 2021 inputs used to represent two different modelled years as a proxy, and output benefit values compared with those produced using the factors described above. The difference between these methodologies is that the latter does not incorporate demand growth.

Demand growth has been incorporated into the factors used to convert single-year benefits. Per-annum demand growth across the appraisal period was calculated using the DfT's 2018 Road Traffic Forecasts (RTF) as shown below in Table 8. The data used was specific to Wales but averaged across all road types.

Table 8 – Background Traffic Growth Rates[12]

	Growth Across Period	Annual Growth
2020-2025	4.62%	0.91%
2025-2030	4.20%	0.83%

TUBA outputs were based on weekdays, excluding weekends and Bank holidays. We applied a weekend and bank holiday factor: 1.4 (based on the proportion of 7 complete week days/ 5 days.

5.2 Ricardo's Model

5.2.1 Vehicle Upgrade costs

A vehicle owner upgrading to cleaner vehicles and the resultant impact on air quality is the key output of each the Charging scheme and vehicle upgrade measures in CASAP. The costs associated with this decision is a critical impact category. Our approach to estimating upgrade costs has been tested in a number of cities considering charging schemes and has been applied in Cardiff when considering the Charging Scheme and Fleet upgrades.

The approach starts by calculating the number of vehicles to be upgraded. For the CASAP measures that has been calculated directly from the fleet data for buses and taxis as described above. For the CAZ this is defined by applying behavioural responses to the non-compliant vehicles in the baseline. It is assumed that the oldest vehicles are the first to upgrade.

The cost to an owner of a change vehicle is then estimated through consideration of the following:

- The lost residual value from scrapped vehicles or the resale value of an unwanted vehicle based on the depreciated value of vehicle in 2021
- New or used vehicle purchase costs in 2021

These input values are combined to give the net cost. Resale costs (if applicable) are netted off the purchase costs and lost residual value associated with each upgrade.

[12] Source: Mott MacDonald from RTF 2018

Upgrades will also occur in the baseline and our approach to estimating these costs is very similar to what has been applied when considering the policy option. The general assumption in the baseline is that the same upgrade decision will be undertaken as in the measure but at a later date (defined by useful lives and ownership profiles). This future net cost is discounted (according to how far in the future it occurs) to 2021 to allow comparison with option costs. The exception to this is for the ZEB measure and electric/PHEV taxis which assume that, in the baseline, these vehicles upgrade to standard, Euro 6, diesel/petrol vehicles.

The upgrade costs are calculated taking the difference in aggregate upgrade costs for the option and baseline scenarios. Specific modelling assumptions and data inputs are provided in the Appendix of this document.

5.2.2 Air Quality Emissions

The key objective of these policy options is to reduce the emission (and subsequently concentrations) of air pollutant emissions from road transport sources. Reducing air pollutant emissions will have a range of subsequent benefits on human and environmental health, productivity and amenity.

The following approach to valuing the impacts associated with reductions in emissions is as follows:

1. Take quantities (tonnes) of emissions from underlying air quality modelling undertaken by Ricardo for all option scenarios and do minimum baseline
2. Calculate total emissions impact relative to baseline
3. Value impact applying damage costs provided by JAQU
    a. The damage cost 'Urban big' is applied to all emissions reductions under the FBC CASAP and CAZ 1 scenario.

The results of the analysis for 2021 are presented in Table 9. It should be noted that these are only impacts for a single year, and there is no application of extrapolation factors.

Table 9 – Air pollutant (NO_x and $PM_{2.5}$) impacts of the measures in 2021

Option	NOx			PM2.5		
	NOx Emissions (t/ year All vehicles)	Difference from Baseline (t)	Benefits per annum (£)	PM2.5 Emissions (t/ year All vehicles)	Difference from Baseline (t)	Benefits per annum (£)
FBC CASAP	1819.68	-99.13	£711,915	62.69	-0.34	£43,915
CAZ Cars only (CAZ 1)	1,925.63	6.81	-£49,919	65.48	0.99	-£322,085

Results show a decrease in NO_x and $PM_{2.5}$ emissions for FBC CASAP with benefits per annum of £711,915 and £43,915 savings respectively. Conversely the results show an increase in NO_x and $PM_{2.5}$ emissions for CAZ 1 with disbenefits per annum of £49,919 and £322,085 costs respectively.

5.2.3 Operating costs and Greenhouse Gas Emissions for Upgraded vehicles

Operating costs and greenhouse gas emissions are calculated as part of the TUBA model. This modelling focuses on the additional impacts associated with any change in distance and therefore fuel consumption associated with a particular option. But TUBA does not take into account any change in fuel consumption (and OPEX and GHG impacts) associated with the upgraded fleet that has resulted from the option. Ricardo's model, which has focused on charging schemes that result in a significant change in fleet mix, calculates the changes in fuel costs, OPEX and greenhouse gas emissions. The values used to calculate these operating costs are consistent across the different forms of analysis.

The estimation of operating costs and greenhouse gas emissions focused on capturing the effect of upgrading vehicles, which switches vkm travelled from one Euro class of vehicles to another. The following approach was taken:

1. Take numbers of vehicles upgraded from fleet upgrade calculations

2. Combine numbers of vehicles upgraded by different vehicle type and Euro standards with data around the average annual fuel consumption and average annual operating costs per vehicle type and age[13]
    a. By applying average OPEX and fuel consumption over the full year and average vkm travelled per annum, this illustrative modelling will likely capture an even wider domain of impacts – i.e. will include the impacts where upgraded vehicles travel outside the AQ modelling domain
3. Changes in fuel consumption are combined with changes in fuel prices.
4. Changes in fuel consumption are combined with emissions factors from BEIS' Green Book Supplementary Guidance to calculate changes in GHG emissions (tCO_2e) [14]
5. Changes in GHG emissions in each year are combined with carbon values from BEIS' Green Book Supplementary Guidance.

Note: these impacts are not forecast over the period using the extrapolation factor. This is because these impacts are associated with modelled vehicle upgrades. The model depicts the OPEX and GHG emissions associated with the new vehicle, and with the vehicle replaced to identify the difference. Hence the impacts are already depicted over the appraisal period and the extrapolation factor is not required.

5.2.4 Implementation costs

Implementation costs are described by JAQU guidance as the costs of implementing a measure in terms of administrative costs. The following assumptions have been applied to calculate the final implementation costs included in the model:

- When looking at the **ZEB costs**, CCC estimated a total of £455,000 covering 45 charge points at £ 10,080 per point, BYD Charging Management System and set-up costs (one-time, including commissioning of the system and training) (see **Error! Reference source not found.**, second and third column). Note this amount does not include any supply/ connection costs.
- In terms of the **retrofit for the buses,** at the time when the model was set up CCC was looking at offering up to 150 buses with costs of £15,000 per bus, giving a total of £2,250,000 (2018) to retrofit 150 buses. These costs are assumed in the REE model for the retrofit bus package to calculate the total upgrading costs. They are not included as such in the implementation costs to avoid double counting.
- The CCC was targeting 620 vehicles which following the change in policy will be required to change to Euro 6 when we developed the model for **taxi licensing**. CCC aimed at contributing £1000 annually over 3 years for the running costs (not purchase) of the vehicles which would equate to a total cost of £3000 per vehicle and a total cost of £1,860,000 for the CCC. Ricardo EE economic model includes not only the purchase but also the running costs (OPEX) to compare the overall benefits of the renovated fleet during the whole appraisal period. Thus, the £1,860,000 costs estimated by the CCC to contributing to the overall costs of taxi licensers are already considered in the REE model and not included as separate implementation costs to avoid double counting.
- In terms of the completion of **Cycle way 1**, the cost estimate is £5,800,000 included in the FBC CBA (see **Error! Reference source not found.**, second and third column). However, it should be noted that the 2019/2020 costs are likely to be funded through the active travel fund (£107,000), so potentially these could be removed as work as already stated on this element if we were to look at non-secured funding costs only (see **Error! Reference source not found.**, fourth and fifth column and Appendix 1 for additional information).
- CCC has a cost estimate of £1,996,480 for the 20mph zones (**Active Travel Package**). This number is thus included as implementation cost in the FBC CBA (see **Error! Reference source not found.**, second and third column). However, it should be noted that bids have already been made for these elements and award announcement is imminent at the time when this study took place, and work has already commenced so potentially these could be removed if we were

[13] Consumption and OPEX for general vehicle types came from: Ricardo study for TfL (2014): 'Environmental Support to the Development of a London Low Emission Vehicle Roadmap' (unpublished). Data for hybrid vehicles came from: Ricardo Energy & Environment (forthcoming). Car Choice Model (CCM) summary report.

[14] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/602657/5._Data_tables_1-19_supporting_the_toolkit_and_the_guidance_2016.xlsx

to look at non-secured funding costs (see **Error! Reference source not found.**, fourth and fifth column).

- The **City Centre Programmes** have a total implementation cost of £22,252,000 which is included in the FBC CBA (see **Error! Reference source not found.**, second and third column). However, £950,000 have been already spent before 2019. Also, £2,750,000 has been awarded for the 2019/2020 financial year from the Local Travel fund and £500,000 from the City Deal. The S106 has also awarded £1,000,000 from the 2019/2020 costs and £250,000 from the 2020/2021. This sums a total of £ £5,450,000[15] that could potentially be removed if we were to look at non-secured funding costs (see **Error! Reference source not found.**, fourth and fifth column and Appendix 1 for additional information).
- **Implementation costs for the CAZ** include the cost to the local authority to set up and run the charging zone, including equipment, and the ongoing costs of ensuring compliance. The numbers are determined by the accessibility of the CAZ area and the number of roads going in and out. There is also an assumed ongoing cost that accounts for maintenance and additional public staff to issue fines, data collection and processing of payments etc. Hence implementation costs are a combination of upfront infrastructure costs and ongoing costs assumed across 10 years.

The additional cycle ways which are included in the AECOM assessment are those that are included in the City Centre Schemes, and thus the costs for those are incorporated into the costs of those schemes and are therefore accounted for.

For the core societal CBA, the costs that have already taken place when this analysis was done (Pre-2019 in Table 5**Error! Reference source not found.**) should be taken into account as they have occurred after 2015, which is the base year for building up the AQ and traffic model and therefore their impacts are taken into account in the FBC CASAP scenario (see **Error! Reference source not found.**, second column). Only when looking at the costs that still need funding, these will be taken out as they have already occurred. This will be the case for the costs of the Cycle Way 1 and the City Centre Scheme in 2018 (£107,000 and £950,000 respectively) (see Table 10, fourth column). We have presented both for comparison.

In addition, a 36% uplift on any implementation costs has been applied as optimism bias following JAQU guidance (see Table 10, third and fifth column for implementation costs with and without secure funding respectively) (see Appendix 2 – Additional Results for results without optimisms bias applied to implementation costs).

Table 10 – FBC CASAP Implementation costs (£2018) included in the Economic Appraisal

Our assumption	Total costs included		Excluded costs with secured funding	
CCC	-	Opt. Bias (36%)	-	Opt. Bias (36%)
ZEB	-£439,614	-£597,874	-£439,614	-£597,874
Bus retrofit	REE model	REE model	REE model	REE model
Taxi Licensing	REE model	REE model	REE model	REE model
Active Travel Package	-£1,418,357	-£1,928,966	-£1,418,357	-£1,928,966
Cycle Way 1	-£5,532,788	-£7,524,592	-£5,425,788	-£7,379,072
City Centre Programme	-£20,652,037	-£28,086,771	-£15,362,543	-£20,893,058
Net Present Value	**-£28,042,796**	**-£38,138,203**	**-£22,646,302**	**-£30,798,971**

5.3 Active Modes Appriasial Toolkit

The demand forecasts using the PCT method described in Section 2.2 have been input into the Active Mode Appraisal Toolkit (ATT) as per Department for Transport (DfT) WebTAG Unit A5-1[16] to appraise

[15] Pre-2019/2020: £950,000; 2019: £4,250,000; 2020: £250,000.
[16] Active Mode Appraisal (May 2018). Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/760092/active-mode-appraisal-toolkit.xlsx

additional economic benefits related to the following specific FBC CASAP measures: Active Travel package and Cycle Way 1. The impacts appraised all relate to an estimate of the reduction in vehicle km for road users which would occur derived from the modal shift to walking/cycling from car. These include the following impacts: decongestion benefits, accidents, local air quality, noise, greenhouse gases, reduced risk of premature death, absenteeism, journey ambience, indirect tax revenue. The ATT is not considering the wider discouragement to drive into the city centre that the overall package would result in, only the impact of the attractiveness of high-quality cycle infrastructure. However, the quantification of the impacts associated with the rerouting of vehicular traffic which may result in additional vehicle kilometres with associated economic dis-benefits is well captured by TUBA.

The model is based upon a desk-based analysis of the proposed walking and cycle measures on each route. A background growth rate in trips of 0.75% (National Travel Survey Data 2006-2016) has been assumed, with 90% of trips being made considered as return trips and therefore counted twice in the daily journey count. As the three schemes have been appraised separately in the Active Travel Toolkit, the method adopted provides the potential for a limited amount of benefit double counting. Scheme implementation costs have been included separately in the overall analysis (see Implementation costs section in page 15).

The assessment period is usually based upon the life expectancy of the infrastructure in question. WebTAG allows to appraise up to a 60 years threshold, but for cycle infrastructure which may have a shorter life expectancy than say a road it is more reasonable to assume 20 years. However, to align with the wider to align with the wider assessment undertaken as part of the air quality study the assessments have been undertaken over a 10-year appraisal period[17] with all scheme assumed to open in 2021. Note that reducing the assessment threshold from 20 to 10 years approximately corresponds to a halving of benefits (see Appendix 2 – Additional Results).

Local air quality, greenhouse gases, and indirect tax revenue have been calculated at the CASAP level using TUBA and therefore not included in the overall economic appraisal to avoid double counting (see Appendix 2 – Additional Results for complete ATT results).

[17] AECOM also carried out a 20-year appraisal threshold in order to take into account the potential life span of the cycle infrastructure. These results are not included in this document for consistencies.

6 Discounting

As recommended by JAQU, our model uses a 2018 price year as the basis for all calculations. This means that past costs (for example vehicle costs) are inflated to 2018 values using HM Treasury's GDP Deflator series. Any costs projections kept in constant 2018 prices and therefore inflation adjustments are not required. Discounting future costs and benefits considers the time preference of society. Discounting is done in accordance with HM Treasury's Green Book guidance. The model applies a discount rate of 3.5% to all impacts, which are discounted back to 2018.

TUBA software usually uses a price base and discount year of 2010 to ensure consistency in assessing transport schemes. Whilst it is possible to edit TUBA inputs to account for this, it is considered simpler to account for these requirements using factors applied externally to TUBA economic outputs. The factors calculated in accordance with WebTAG Unit A1.1 and the latest version of the WebTAG Databook. We applied a price base adjustment factor of 1.142 (2010 to 2018) and discount adjustment (1.317) to all TUBA outputs and shift the price base and discount year from 2010 to 2018 and ensure consistency with the rest of the analysis[18].

We provide the year to year factors applied to TUBA outputs to adjust for adjusting price base and discount year, changing values of time (for VoT-related benefits only), and demand growth in Table 15 of the Appendix 1.

[18] Adjustment factors, WebTag 2018.

7 Results

7.1 Summary of results

The results of our economic analysis are summarised in Table 11 and Figure 3.

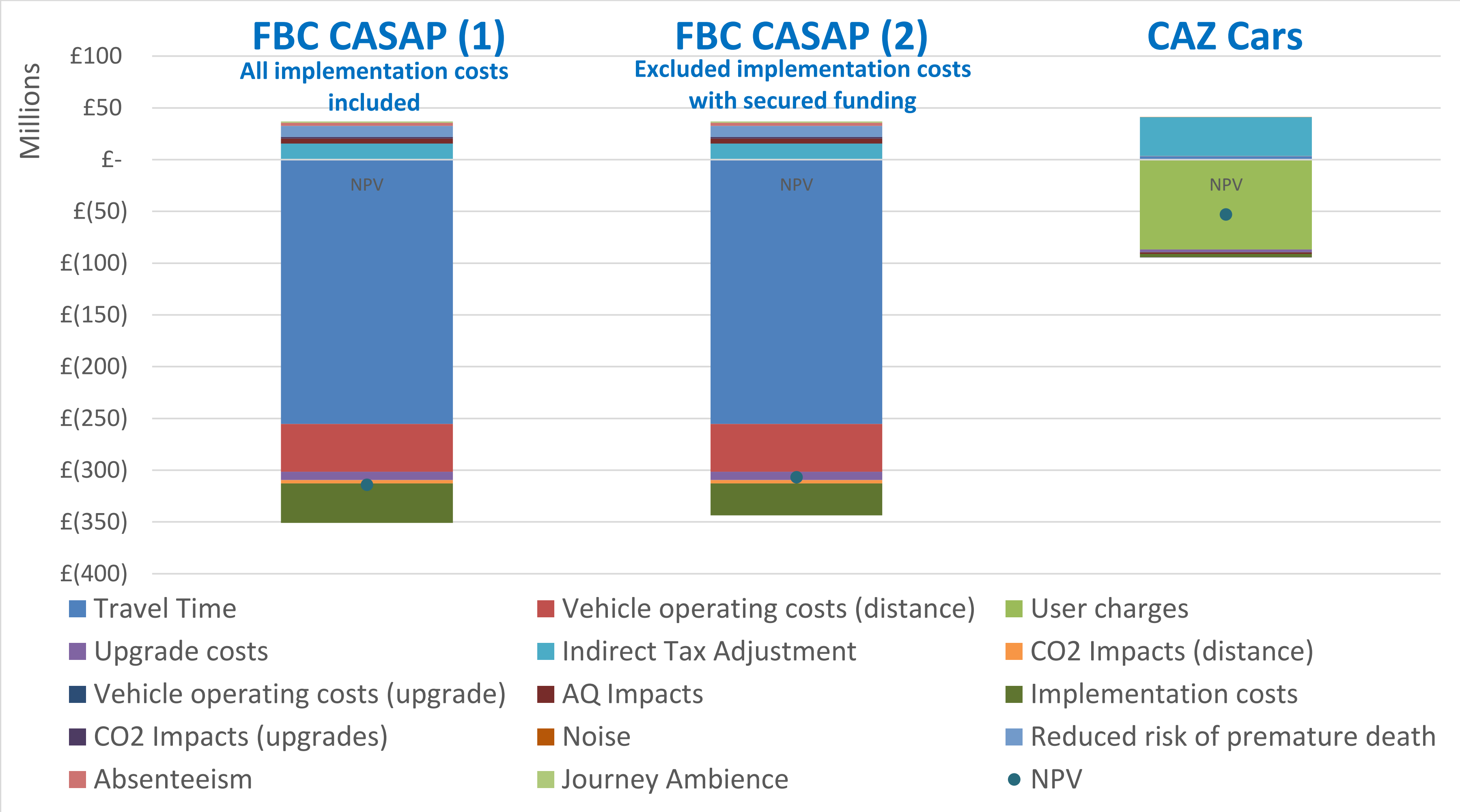
Table 11 - Monetised impacts associated with option scenarios (cumulative discounted impact (PV) from 2021-31 (£m 2018 prices))

	FBC CASAP		CAZ Cars
Thousand £	All implementation costs included	Excluded costs with secured fudning	-
Travel Time	-£255,412	-£255,412	£3,270
Vehicle operating costs (distance)	-£46,032	-£46,032	£299
User charges	£-	£-	-£86,762
Indirect Tax Adjustment	£15,557	£15,557	£37,589
CO_2 Impacts (distance)	-£3,405	-£3,405	£202
TUBA Partial NPV	-£289,292	-£289,292	-£45,401
Upgrade costs	-£7,973	-£7,973	-£2,473
Vehicle operating costs (upgrade)	£7	£7	-£315
AQ Impacts	£4,861	£4,861	-£1,439
Implementation costs	-£38,138	-£30,799	-£3,279
CO_2 Impacts (upgrades)	£1,406	£1,406	£58
REE Partial NPV	-£39,837	-£32,498	-£7,564
Accidents	£118	£118	£[19]-
Noise	£8	£8	£-
Reduced risk of premature death	£10,861	£10,861	£-
Absenteeism	£2,995	£2,995	£-
Journey Ambience	£1,056	£1,056	£-
AECOM partial NPV	£15,038	£15,038	£-
TOTAL NPV	**-£314,091**	**-£306,752**	**-£52,965**

Notes: +ve values denote benefit / -ve values denote costs; all impacts are in 2018 prices; all impacts are discounted to 2018

[19] It is assumed that there will be a change in the level of accidents as more people switch to active travel measures, however it is assumed that these impacts are captured in the 'user costs'

Figure 3 – PV of impacts and NPV of option scenarios



Note: Bars represent present value (PV) of impacts; dots represent aggregate net present value (NPV) of all impacts associated with CAZ option; all impacts are assessed relative to 'do nothing' baseline; all impacts presented in 2018 prices.

7.2 Commentary on results

7.2.1 CAZ 1 Results

7.2.1.1 TUBA Outputs

Travel times

The implementation of the Clean Air Zone results in a monetised travel time benefit of £3,270,417. The first order behavioural changes modelled in this scenario assume that a significant proportion of the vehicles that travel into the area either cancel their trip or avoid the charging area, this results in fewer vehicles on the road and improved travel times for the remaining vehicles. The monetised benefit of this reduced travel/congestion time is modelled here.

However, it is worth noting that the rerouting that occurs from avoiding the charging area may result in congestion in other areas (and a time loss) therefore the overall net benefit shows us that the time saved from individuals cancelling their trip/avoid the city centre, is significantly greater than the additional congestion occurring beyond the charging area.

Vehicle operating costs (distance)

The increased mileage of vehicles attempting to avoid the CAZ and also cancelling in response also impact the ongoing operational cost of the vehicles. The impact of this has a net benefit of £299,302. However, this does not include the operating cost benefit from vehicles that upgrade which is calculated separately.

Welfare costs

The welfare costs, which include the user charge for vehicles entering the clean air zone, and the disutility from vehicles that choose not to enter the charging zone, has a net cost of £86,762,293. This is the largest single impact of the CAZ option and includes the daily £10 charge that non-compliant vehicles will be required to pay to enter the clean air zone as well as the utility cost to individuals who would have travelled in to the zone in the absence of a charging mechanism. The cost for individuals who no longer travel in to the charging zone is calculated by *rule of half* which assumes that lost utility is half the cost of the charge the enter the zone (£5) and applied for every day that a person would have otherwise travelled in to the area.

Indirect tax adjustments/revenue

The revenue received by the local authority is also assessed as a benefit. Here the indirect tax adjustments and revenue from the charging zone provide a benefit of £37,588,777. However, it should be noted that a significant proportion of this impact that is equal to the cost to individual drivers who enter the clean air zone, the cost of which is captured in the welfare costs, and so there is a netting out of the charging costs.

CO_2 impacts (distance)

The reduced travel time results in a reduction in the amount of CO_2 given off. This has a positive impact on the environment (and goes toward to UK governments greenhouse gas targets) resulting in a monetised benefit of £202,469.

7.2.1.2 Ricardo model outputs

Implementation costs

The implementation of the Clean Air Charging Zone is based on the infrastructure and personal needed to set it up and ensure that vehicles are compliant. The implementation cost is estimated at £3,278,752 This includes both the initial capital expenditure to set up to clean air zone and the ongoing operational expenditure over the 10-year appraisal period. Moreover, a 36% optimism bias is included in the cost of implementing the CAZ to account for any potential under costing for implementing such transport measures.

Upgrade Costs

The costs to individuals that choose to upgrade to a compliant vehicle is £2,473,138. This is based on the assumption that 17.6% of the 175,000 vehicles modelled will upgrade. The value represents the additional cost incurred through upgrading before individuals would have chosen to purchase a new vehicle had the CAZ not been introduced. The upgrade value is one of the most significant costs associated with the introduction of a CAZ and is the largest impact modelled in the Ricardo Economics Model.

The economics model assumes that everyone upgrades their vehicle the year that the CAZ is introduced (2021). Under the baseline, individuals are expected to upgrade at some point during the 10-year appraisal period. As a result, the upgrade cost is a net impact as people may upgrade when their current vehicle reaches the end of its lifespan in the baseline.

Fuel Costs (upgrade)

The change to the vehicle fleet has a resultant impact on the fuel consumed by the new fleet. The nature of the baseline fleet means that a proportion of the fleet will switch vehicles from a non-compliant Euro 4 and 5 Diesel vehicle to a compliant petrol Euro 4 and 5 petrol vehicle (with the rest upgrading to compliant diesel vehicles). While this has a positive impact on the air pollution, petrol vehicles are less fuel efficient than diesel cars and hence the total fuel consumed increases as a result. The total fuel consumption change has a net cost of £422,895.

Vehicle OPEX (upgrade)

The benefit associated with reduced vehicle OPEX is £107,769, which is due to the reduction in ongoing maintenance costs required for newer vehicles. The reduction in ongoing costs is expected to continue after the implementation of the Clean Air Zone until 2026, the assumed maximum lifetime that vehicles would have been on the road for before upgrading under the baseline. After 2026 it is assumed that all vehicles under a ‘do nothing’ scenario would have upgraded anyway and hence there is no net OPEX benefit.

CO_2 impact (upgrade)

The change in CO_2 is a direct result of the additional fuel consumption that occurs due to the fleet change and particularly the fuel change. The increased fuel used therefore has a further cost associated with the CO_2, the cost of which is £57,779. As discussed in the Fuel Costs, a proportion of non-compliant, Euro 4 and 5 diesel vehicles will switch to compliant, Euro 4 and 5 petrol vehicles. As petrol vehicles consume more fuel than diesel, it will result in more CO_2 being emitted, and hence a net cost overall.

Air Quality Impact

The change in air quality that results from the implementation of the Clean Air Zone has a net cost of £1,439,102. This is because overall emissions of both NO_x and $PM_{2.5}$ are shown to increase as a result of introducing the CAZ. While the increase in NO_x is greater than in $PM_{2.5}$, the cost associated (stemming from the health impact) is significantly greater for $PM_{2.5}$.

The increase in NOx is due to the small area of the charging zone compared to the larger Air Quality modelling area over which the air quality analysis is conducted. While it is expected that the air quality will improve within the CAZ boundary, the transport and air quality modelling also suggests that traffic will choose to travel around the CAZ area rather than through it. This results in an increase in NO_x emissions across the entire modelling area. Nevertheless, while this is a net cost, the change in emissions does not look at where the emissions levels are the most serious. The largest Air Quality Management Areas (AQMAs) is inside the CAZ boundary hence the implementation of the charging zone will likely go a long way to reducing the pollution concentration in this key area. Nevertheless, the modelled air quality area covers the rest of the city centre, hence raising pollution levels outside the CAZ boundary is still of concern given that it will still result in significant expose to residents and visitors.

7.2.2 FBC CASAP Results

7.2.2.1 TUBA Outputs

The CASAP package included a number of different measures that affect travel times and distances including the active travel package and the city centre schemes. These measures have their own cost and benefits associated, however the have been modelled as a single package n the transport model and so the TUBA results cannot be disaggregated to show the impacts of different measures hence we cannot know for certain where the costs and benefits reported below come from.

Travel times

The CASAP measures has a net travel time impact of -£255,412,231. The nature of specific road measures means that travel time is likely to increase in the short term while these measures are implemented, however the potential congestion reduction in the long term is not modelled. Moreover, the effects in the CASAP measures are dominated by the Westgate Street and Eastside schemes, which make it more difficult to access or traverse the city centre. These schemes apply to a significant number of vehicles in a congested area and so lead to increases in travel time and OPEX. In contrast the active travel measures apply a relatively modest mode shift from car driver to trips with both an origin and destination in a defined area. In short, significantly more vehicles are affected by the changes to the layout in the city centre than removed from the demand matrices by way of the active travel measures.

It is important to remember however, that the city centre schemes have been modelled with a fixed demand in the transport model. Therefore, the modelling of travel times only accounts for traffic diversion rather than any switching of mode or trip supersession. In reality we are likely to see a percentage of trips switch to other means of transport or be cancelled which would reduce the time impact, as well as have a number of knock on effects of reduced traffic levels. This is an important limitation of the modelling and does not allow one of the key benefits of the City Centre schemes to be fully assessed.

It should also be noted that there are specific mitigation measures that are being considered in terms of Improvement Corridor Projects to support mode shift in relation to the city centre schemes that have not been included in the modelling as they are still being developed. The modelling does also not take into account longer term major transport projects identified by the forthcoming New Transport Vision which would be likely to affect journeys times over the 10-year appraisal period.

Vehicle operating costs (distance)

Given the increased travel time and distance there is also an increased cost associated with the additional distance that vehicles will be driving. The monetised impact of this is -£46,032,340. This is likely to be due both to the impact of the additional measures themselves as well as additional driving in an attempted to avoid the measures.

Welfare costs

While there is potentially a welfare loss associated with individuals being required to change their preferred route of travel, this disutility is only captured in the indirect tax adjustment.

Indirect tax adjustments/revenue

There is overall indirect tax benefit of £15,557,340 as a result of the various different CASAP measures introduced.

CO_2 impacts (distance)

The increase in overall journey time for individuals has an impact of the amount of CO2 emitted. The overall monetised impact from the additional CO_2 in the atmosphere as a result is -£3,404,932.

7.2.2.2 Active Travel Tool outputs

The increase in overall walking and cycling has a net benefit of £15,038,580. Reduced risk of premature death shows the highest benefits (£10,861,200), followed by absenteeism (£2,995,440), journey ambience (£1,056,020) and accidents (£118,060). Noise shows the lowest net benefit (£7,860). The results show the changes to Cardiff City Centre being implemented will provide significant economic benefits to cyclists along these routes. The overall result from the Active Travel Toolkit Assessment is shown in Appendix 2.

7.2.2.3 Ricardo model outputs

Implementation costs

The combined measures within the FBC CASAP package has a net cost of £38,138,203. The costs will vary across as summarised in **Error! Reference source not found.**. The nature and variety of the different measures involved in the CASAP approach results in a large net cost to implement them, the majority of which stems from the two city centre schemes. While the cost is significant, the traffic schemes are expected to bring a large benefit to the city centre once completed.

Upgrade Costs

Various measures within the CASAP package will generate fleet upgrades to buses and taxis to newer vehicles with lower emissions. While it has an environmental benefit, the upgrading that occurs has a net cost of -£7,972,573 to the bus and taxi fleet.

Operating Costs (fuel and opex)

There is a net operating benefit associated with the CASAP measures of £6,920. While the net benefit is relatively small. The associated fuel and operating costs are much more significant. The measures looked at result in an overall fuel cost saving of £1,416,730. The majority of this benefit comes from bus and taxis that upgrade to EVs and PHEV (although the new electricity cost is included). Moreover, the analysis assumes that under the baseline these vehicles upgrade to Euro VI, providing a more sustained economic benefit to the upgrade package.
Conversely, the measures result in an ongoing operation cost of £1,409,810. This is due to the assumption that newer vehicles are more expensive to maintain, counterbalancing the savings made through reduced fuel consumption

CO_2 reduction

Upgrading to new, more environmentally friendly vehicles also reduced the amount of CO_2 that the vehicles emit, this has a wider benefit of the society that can be monetised. This benefit is calculated at £1,405,811.

Air Quality Impact

The combined measures included within CASAP significantly improve the overall air quality within Cardiff. The overall emission reduction is given in **Error! Reference source not found.**. Here the benefit is monetised to account for the wider savings that occur due to reduced mortality and hospital admissions. The benefit of the reduced emissions across the whole package is £4,860,916 which is much greater than the CAZ.

Moreover, the vehicle and method of transport shift that occurs under the CASAP does not have the same 'baseline catch-up' observed under a CAZ. For example switches to cycling are not expected to happen in the baseline and buses and taxis that upgrade to EV's in the CASAP scenario, are only assumed to upgrade to Euro VI under the baseline, creating a more sustained benefit.

Overall, air quality impacts accounted for here demonstrate a real reduction in pollution and associated increased health standards, as opposed to the CAZ measure which has been shown to displace, rather than reduce emissions.

Lastly as discussed in relation to travel changes for the CASAP package the full benefit of the city centre schemes in terms of potential mode shift has not been captured and if this were accounted for it would be likely to improve the emissions and air quality benefit further.

8 Conclusion

The nature and significance of the impacts associated with the FBC CASAP measures and the CAZ option vary substantially. Both schemes have a negative NPV, i.e. the costs outweigh the benefits, and the FBC CASAP has a larger negative NPV (£314,090,793 vs £52,951,224). So, in general terms while both assessed options achieve compliance, the CAZ option achieves this at a lower overall social cost than the CASAP scheme. However, the story is more complex than this top line figure.

The source of the large negative NPV is different under the two measures. Under the CASAP, the dominant proportion of the disbenefit comes from the additional travel time calculated in TUBA. However, the transport modelling underlying the TUBA calculation does not take in to account the demand response for the city centre measures (assuming that people re-route, rather than change modes of transport) and so is likely to be an overestimate (or at least give a maximum) of the travel time disbenefit. A change in modelling approach to account for this would therefore be likely to reduce this time disbenefit.

It should also be noted that there are specific mitigation measures that are being considered in the form of Improvement Corridor Projects to specifically to mitigate the travel time impacts of the city centre schemes and encourage wider mode shift. These schemes, which have not been included in the modelling, would further serve to reduce this time disbenefit. Lastly the modelling does also not take into account longer term major transport projects identified by the forthcoming New Transport Vision which would be likely to affect journeys times over the 10-year appraisal period.

On the other hand, the largest impact affecting the CAZ measure is the user charges, which are expected to be a large cost to the public, as a proportion of whom will still wish to drive in to the city centre in non-compliant vehicles and pay the charge. Some of this cost is then recuperated in economic benefit to the city council, which is captured elsewhere in the model. In relation to travel time impacts the CAZ scheme has some generic assumptions that have been applied in the transport model in relation to mode shift and trip suppression as a result of the charge, giving a more optimistic assessment of travel time impacts of the CAZ scheme compared to the CASAP scenario.

Also importantly, although both schemes achieve compliance with the NO_2 limit values, overall the CAZ scheme generates an increase in emissions and so has an overall air quality and health disbenefit. This compares with the CASAP scheme that has a positive overall and continuing emissions, air quality and health benefit. So, although both meet the legal test of achieving compliance only the CASAP option actually generates overall health benefits for Cardiff.

Moreover, there are further health benefits associated with the active travel component of the CASAP scheme, captured by the Active Modes Toolkit, which are not present for the CAZ scheme. These active travel benefits have also likely been underestimated as the potential mode shift associated with the city centre package has not been accounted for within the modelling approach used.

It is also worth discussing who the different measures will affect the most. The key response to the CAZ measure is that it will require people to purchase a new vehicle in order to avoid paying the charge. This will likely disproportionally affect the poorest amongst the community who are likely to currently have the oldest vehicles and may not be able to afford to purchase a compliant vehicle. Moreover, for those who cannot afford to purchase a new vehicle and who may be forced to pay the charge, the fine will be a significantly larger proportion of their disposable income than for more affluent people who can afford to pay/upgrade their car.

Under the CASAP measures, bus companies and taxi drivers are required to purchase compliant vehicles (albeit with some funding assistance), which may in turn increase the cost of these modes. While less directly correlated this may also have a disproportionate impact on the poorest, who disproportionately take the bus (and whose fares may get raised, particularly from the private operator). Moreover, taxi drivers are also one of the lowest paid professions in a city. Divers will have to purchase a new compliant vehicle, and many of whom may find this difficult to afford. For a more detailed discussion of these impacts, see the distributional impact assessment.

Finally, one further limitation of assess CAZ and CASAP measures is that we cannot take in to account the knock-on effects of other cities implementing their own strategies. We have seen an increasing number of cities introducing measures to reduce air pollution around the UK, which in addition to benefiting their own population, will have a broader knock on effect that is harder to quantify. People travel around, as such as more cities begin regulate for cleaner vehicle, people will upgrade their cars sooner. This is likely to be particularly true of HGVs and Coaches who tend to enter multiple cities regularly. It will also incentive more people to buy Euro 6/PHEV/EV vehicles which will increase demand and reduce the cost. Reducing the economic impact on individuals in a way that is difficult to account for in our assessment.

Appendix 1 – Data inputs

Table 12 – City Centre Programme Budget as provided by the CCC, in £000s (£2018)

City Centre Programme Total	Pre 2019/20	2019/20 projected	2020/21	2021/22	2022/23	Later	Total
Surveys	590	380	20	50	0	0	1,040
Design	316	270	9	80	0	0	675
Land Purchase	0	0	0	0	0	0	0
Accommodation Works	44	205	433	108	118	0	908
Construction	0	3,100	8,900	3,000	3,000	0	18,000
Project Management	0	280	751	243	255	0	1,529
Monitoring and Evaluation	0	0	30	0	30	0	60
Promotion	0	10	20	0	10	0	40
GROSS TOTAL	950	4,245	10,163	3,481	3,413	0	22,252
Match funding amount, percentage contribution and funding source(s) *(insert name of organisation)*	0	0	0	0	0	0	0
NET TOTAL	950	4,245	10,163	3,481	3,413	0	22,252
LTF Funding		**2,750**	2,500				
Clean Air Fund		0	5,000				
City Deal		**500**	2,500				
S106		**1,000**	**250**				
Other							
Total		**4,250**	10,250				
+/-		+5	+87				

Note: In bold funding already secured.

Table 13 – Cycle Way 1 Budget as provided by the CCC, in £000s (£2018)

Cycle Way 1 -	£000s Pre 19/20	£000s 2019/20	£000s 2020/21	Total £000s
Surveys	0	33	6	39
Design	0	194	0	194
Land Purchase	0	0	0	0
Accommodation Works	0	61	0	61
Construction	80	1,057	4,074	5,211
Project Management	27	109	193	329
Monitoring and Evaluation	0	5	15	20
Promotion	0	5	9	14
GROSS TOTAL	107	**1,464**	4,297	5,868

Note: In bold funding already secured.

A summary of the key assumptions applied in the analysis is set out in Table 14.

Table 14 – Summary of Key Assumptions

Assumption	Assumption	Source
Appraisal Assumptions		
Discount Year	2018	JAQU
Price Year	2018	JAQU
Appraisal Period	10 years (2021 to 2031)	Expert judgement
Discount Rate	3.5%	JAQU HM Treasury GDP Deflators[20], as recommended by JAQU
Air Quality		
Damage Costs (air quality and GHGs)	Various values	JAQU Guidance for damage costs; carbon prices taken from: BEIS Supplementary Green Book Guidance (2016)
Impact extrapolation factor	Various values	Derived from analysis of scenario concentration results from Defra Air Quality National Plan
Fleet Assumptions		
Vehicle Types	As defined by JAQU – but the Charging Model combines HGVs (rigid and articulate) and Coaches (coach, minibus) and buses (single and double) into single categories to make the model more manageable.	JAQU/ Expert judgement
Vehicle fleet composition	Various values	ANPR data and air quality model
Fleet projection (vkms/vehicles)	Various values	Transport model, ANPR data and fleet projection tool Ricardo study for TfL (2014): 'Environmental Support to the Development of a London Low Emission Vehicle Roadmap' (unpublished)
Number of vehicles entering the target area	Various values	Transport model and ANPR data, plus supporting assumptions

20 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/624528/GDP_Deflators_Qtrly_National_Accounts_June_2017_update.xlsx

Annual unique vehicles	Conversion factors to convert ANPR data to annual vehicle numbers	Expert judgement
Growth in overall vehicle fleet	Growth of the vehicle fleet between 2016 and 2020	Ricardo study for TfL (2014): 'Environmental Support to the Development of a London Low Emission Vehicle Roadmap' (unpublished)
Change in fleet composition projection	Change in the vehicle fleet composition between 2016 and 2020	ANPR data and NAEI national trend in fleet
Annual unique vehicles	Conversion factors to convert ANPR data to annual vehicle numbers	Expert judgement /
Change in fleet composition projection	Change in the vehicle fleet composition between 2016 and 2020	ANPR data and NAEI national trend in fleet
Behavioural Assumptions		
Upgrade to new (Charging Scheme)	If upgrade response is triggered, then 25% of those upgrading will purchase a new vehicle and 75% will replace their non-compliant vehicle with a second-hand compliant vehicle	JAQU
Fuel switch (Charging Scheme)	Of those replacing their vehicle with a second-hand complaint variant, 25% will purchase the cheapest complaint vehicle of the same fuel type, while 75% will purchase the cheapest compliant vehicle (for example, in a charging clean air zone diesel will switch to petrol).	JAQU
Scrappage/Fleet size (Charging Scheme)	For every vehicle purchased new, due to an upgrade response, another vehicle will be scrapped.	JAQU
Trips proportional to response	Those vehicles making the most trips into the zone are the most likely to upgrade.	JAQU
Costs Associated with Upgrades		
Emission factors	Various values	Emissions factor Toolkit 2017 v8.0
Annual emissions of NOx and other pollutants (baseline and option scenarios)	Various values	Air Quality Model (Ricardo)

Ownership profile	A four-year ownership profile is assumed for vehicle users. I.e. on average vehicle users' own vehicles for 4 years, before replacing them. In 2020 vehicles that are resold are expected to be halfway through this profile (2 years remaining).	Expert judgement
Euro standard age	Vehicles of different Euro standards are assumed to the youngest possible age for that standard in 2020 with the exception of used ULEV which in 2020 are assumed to be 3 years old.	Euro standard introduction dates
Remaining life of vehicle	Where the age of the vehicle is greater than the life of vehicle, 2 more years is assumed.	Expert judgement
Resale of used, non-compliant vehicles profile (Charging Scheme)	Different resale profile for different Euro standards – different proportions of vehicles are either scrapped or resold depending on vehicle age. Older vehicles are more likely to be scrapped, newer vehicles likely to be resold.	Expert judgement
Scrappage of non-compliant vehicles replaced by new vehicles (Charging Scheme)	Older vehicles are likely to be scrapped first	Expert judgement
Baseline upgrade response (Charging Scheme)	Assume same upgrade decision will be undertaken in baseline as in the measure but at a later date (defined by useful lives and ownership profiles). This future net cost is discounted (according to how far in the future it occurs) to 2020 to allow comparison with option costs	Expert judgement
Average value of new vehicle by type		JAQU upgrade costs
Vehicle depreciation	Various values	JAQU guidance
Fuel consumption per vehicle	Various values	Ricardo study for TfL (2014): 'Environmental Support to the Development of a London Low Emission Vehicle Roadmap' (unpublished) and Ricardo Energy & Environment (forthcoming): Car Choice Model (CCM) summary report

Fuel costs	Various values	LRVC from BEIS Supplementary Green Book Guidance
CO_2 Emission factors	Various values	BEIS Supplementary Green Book Guidance (2016), as recommended by JAQU
Conversion Factors	Conversion factors to allow conversion from fuel consumption to CO2 emissions	DECC DUKES Annex A[21]
Operating cost	Various values	Ricardo study for TfL (2014): 'Environmental Support to the Development of a London Low Emission Vehicle Roadmap' (unpublished)
Implementation		
Charging Scheme Charge	JAQU: £12.50 / day Car, LGV, TAXI, Private Hire Local authority (CAZ 1): £10 charge for private cars entering city centre charging clean air zone.	JAQU/Local Authority
Implementation costs	Costs of implementation (capital costs and operating costs)	Charging scheme from CCC

Table 15 – Year to Year factors applied to TUBA single year outputs

Year	Background traffic growth factor annual	Background traffic growth factor compound	Discounting to modelled year 2021	VOT growth factor compared to modelled year	Relative proportion of non-compliant vehicles in the fleet
2021	1	1	1	1	1
2022	1.00909	1.00909	0.96618	1.01922	0.85
2023	1.00909	1.01826	0.93351	1.03879	0.69
2024	1.00909	1.02751	0.90194	1.06165	0.55
2025	1.00909	1.03685	0.87144	1.085	0.43
2026	1.00827	1.04542	0.84197	1.10887	0.32
2027	1.00827	1.05407	0.8135	1.13327	0.24
2028	1.00827	1.06278	0.78599	1.1582	0.17
2029	1.00827	1.07157	0.75941	1.18368	0.12
2030	1.00827	1.08043	0.73373	1.20972	0.09

[21] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/642725/Annex_A.pdf

Appendix 2 – Additional results

Table 16 shows all results provided by AECOM based on the Active Travel Toolkit.

Table 16 – Active Travel Toolkit Full 10-Year benefit results (Source: AECOM, 2019)

Cost	City centre East	City Centre West	Cycleway	SUM
Congestion benefit	£156,200.00	£114,300.00	£137,570.00	£408,070.00
Accidents	**£45,190.00**	**£33,070.00**	**£39,800.00**	**£118,060.00**
Local Air quality	£220.00	£160.00	£190.00	£570.00
Noise	**£3,010.00**	**£2,200.00**	**£2,650.00**	**£7,860.00**
GHG Gas	£8,060.00	£5,900.00	£7,100.00	£21,060.00
Reduced risk of premature death	**£4,157,360.00**	**£3,042,200.00**	**£3,661,640.00**	**£10,861,200.00**
Absenteeism	**£1,146,570.00**	**£839,020.00**	**£1,009,850.00**	**£2,995,440.00**
Journey Ambience	**£213,830.00**	**£376,170.00**	**£466,020.00**	**£1,056,020.00**
Indirect Taxation	-£35,720.00	-£26,140.00	-£31,460.00	-£93,320.00
NPV	£5,694,720.00	£4,386,880.00	£5,293,360.00	£15,374,960.00
NPV - without double counting	**£5,565,960.00**	**£4,292,660.00**	**£5,179,960.00**	**£15,038,580.00**

Note: in bold impacts included in the overall Economic Assessment.

Table 17 shows the results for FBC CASAP (with and without optimisms bias) and CAZ 1 .

Table 17 - Monetised impacts associated with option scenarios with and without optimisms bias (cumulative discounted impact (PV) from 2021-31 (£m 2018 prices))

	All included (Retrofit and Taxi in REE)		Excluded costs with secured funding		CAZ Cars
	without optimisms bias	with optimisms bias	without optimisms bias	with optimisms bias	with optimisms bias
Travel Time	-£255,412,231	-£255,412,231	-£255,412,231	-£255,412,231	£3,270,417
Vehicle operating costs (distance)	-£46,032,420	-£46,032,420	-£46,032,420	-£46,032,420	£299,302
User charges	£-	£-	£-	£-	-£86,762,293
Indirect Tax Adjustment	£15,557,340	£15,557,340	£15,557,340	£15,557,340	£37,588,777
CO2 Impacts (distance)	-£3,404,332	-£3,404,332	-£3,404,332	-£3,404,332	£202,469
TUBA Partial NPV	-£298,292,243	-£298,292,243	-£298,292,243	-£298,292,243	-£45,401,328
Upgrade costs	-£7,972,573	-£7,972,573	-£7,972,573	-£7,972,573	-£2,473,138
Vehicle operating costs (upgrade)	£6,920	£6,920	£6,920	£6,920	-£315,126
AQ Impacts	£4,860,916	£4,860,916	£4,860,916	£4,860,916	-£313,235
Implementation costs	-£28,042,796	-£38,138,203	-£22,646,302	-£30,798,971	-£3,278,752
CO2 Impacts (upgrades)	£1,405,811	£1,405,811	£1,405,811	£1,405,811	-£57,779
REE Partial NPV	-£29,741,723	-£39,837,130	-£24,345,229	-£32,497,897	-£7,563,896
Accidents	£118,060	£118,060	£118,060	£118,060	£-

Noise	£7,860	£7,860	£7,860	£7,860	£-
Reduced risk of premature death	£10,861,200	£10,861,200	£10,861,200	£10,861,200	£-
Absenteeism	£2,995,440	£2,995,440	£2,995,440	£2,995,440	£-
Journey Ambience	£1,056,020	£1,056,020	£1,056,020	£1,056,020	£-
AECOM partial PNV	£15,038,580	£15,038,580	£15,038,580	£15,038,580	£-
TOTAL NPV	**-£303,995,386**	**-£314,090,793**	**-£298,598,891**	**-£306,751,560**	**-£52,965,224**

Notes: +ve values denote benefit / -ve values denote costs; all impacts are in 2018 prices; all impacts are discounted to 2018

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Cardiff Clean Air Zone Study - Distributional Analysis Results and Methodology Report

Report for Cardiff City Council

ED 11182 | Issue Number 1.6 | Date 03/06/2019

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Cardiff City Council

Customer reference:

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Ref: ED11182- Issue Number 1.6

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1 Introduction

Cardiff, like many cities across the UK, continues to have areas of poor air quality and has been identified as one of the cities where some areas will continue to exceed the nitrogen dioxide (NO_2) limit values beyond 2020. The national air quality plan has identified 2 specific roads that are likely to continue to exceed the Air Quality Directive Limit values: the A48 coming into the city from the North East and the A4232 to the South West of the city centre. In addition, the city has declared 4 Air Quality Management Areas (AQMAs) in relation to NO_2 exceedances. There are two in the city centre: the city centre AQMA and the Stephenson Court AQMA. The other AQMAs are the Llandaff AQMA to the North West of the centre and the Ely Bridge AQMA to the West of the centre.

Source apportionment assessment carried out by the Council has identified that diesel cars and vans are the main contributor to NO_2 concentrations in both the AQMAs and the national exceedance roads. The exception to this is the city centre AQMA which has a large contribution from bus and coach traffic. Cardiff is the largest city in Wales and a major base of employment in South Wales, as such any action to improve in air quality in Cardiff will not only benefit residents of the City but also people commuting into the capital from the wider region. In addition, any action to address the health impacts of air pollution in Cardiff can play a critical role in supporting other priorities such as active travel, health inequalities, integrated care, sustainability, growth and regeneration, localism and community engagement.

Because of these air quality issues and the potential for wider benefits across Cardiff and South Wales, the Council has been directed by the Welsh Government to carry out a Clean Air Zone feasibility to develop a plan that will achieve compliance with the Air Quality Directive in the shortest possible time. The City has already been developing a Clean Air Strategy (CAS) setting out key measures to improve air quality in the city. This strategy provides an initial starting point for a formal plan, along with the consideration of potential charging-based access restrictions, to ensure compliance with the limit values in the shortest possible time.

Ricardo has been commissioned by the Cardiff City Council to deliver the Distributional Analysis Assessment (referred to as DA) of the options being considered. This report sets out the detail of the methodology and data sources used to undertake distributional analysis of the refined shortlist of options, along with the results of the analysis. These results should be seen alongside the core cost-benefit analysis (presented in the Economic Results and Methodology Report) as part of the evidence base for the overarching Economics Case.

The distributional analysis inherently relies on other areas of the modelling undertaken to support the assessment of CAZ options, specifically the transport and air quality modelling undertaken by Mott Macdonald and Ricardo respectively. This report clearly references where the analysis has used the outputs of other modelling and describes how these outputs are used. However, it does not set out a detailed account of how this supporting modelling has been undertaken, which has been provided elsewhere (e.g. the Air Quality Modelling Methodology report).

This report sets out the approach and results of the distributional analysis around the Clean Air Zone Option 1 (CAZ 1) and the final version of the Clean Air Strategy Action Plan (FBC-CASAP). Unlike cost-benefit analysis, which assesses the impacts associated with the CAZ options in an aggregate way using average values, distributional analysis seeks to understand whether there are any specific patterns in the distribution of the impacts, and to explore whether any option unduly favours or disadvantages a particular group. This can inform measures to mitigate the impact of the policy on those groups or amendment of the policy itself.

2 Methodology

2.1 Overview

WebTAG[1] has provided detailed guidance regarding the appraisal of policy options. This provides a steer for many of the key data inputs and assumptions that have framed the analysis undertaken.

The methodology used to undertake the DA is based on the WebTAG guidance. In some cases, we have sought alternative methods, or elaborated additional steps and assumptions where the study team felt that such approaches were warranted to facilitate or improve the analysis. In particular, this is the case where additional output metrics were deemed useful to convey the distributional impacts of the policy options. These distribution impacts should be explicitly stated and quantified wherever feasible.

The results of the assessment of the impact significance are summarised using a seven-point scale, as it is stated by WelTAG:

- Large beneficial (✓✓✓);
- Moderate beneficial (✓✓);
- Slight beneficial (✓);
- Neutral (-);
- Slight adverse (x);
- Moderate adverse (xx)
- Large adverse (xxx).

2.2 Selecting options for assessment

After consultation with the Cardiff, two options have been selected for further assessment and are listed below:

1. CAZ 1
2. FBC-CASAP (referred to as CASAP)

These options are presented in Table 1:

Table 1: Scenarios for appraisal included in the DA compared to baseline for the year 2021

Option	Measure description
CAZ 1	£10 charge for private cars entering the city centre
CASAP	• Buses: 36 buses upgrade to electric vehicles; 80% of buses upgrade to Euro 6 • Taxis: Taxis older than 10 years old upgrade to a newer (4 years old) vehicle; 5% of hackney cabs and 20% of private hire vehicles upgrade to an electric vehicle • A city centre package comprising a bus gate at Westgate Street; the East side scheme and Castle street scheme • An Active travel package comprising the CS1 cycle scheme and 20mph zones for walking and cycling

2.3 Screening of impacts

The screening step was undertaken with reference to the list of impacts detailed in the Webtag A4.2. Impacts were 'screened in' (i.e. for inclusion in the distributional analysis) or 'screened out' (i.e. excluded) taking into account the likely local issues of the proposed options. A summary of the screening is included in **Error! Reference source not found.**.

[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/638644/TAG_unit_a4.2_distrib_imp_app_dec2015.pdf

On the basis of the screening, the following effects have been ‘screened-in’:

1. Air quality - changes in concentrations of NO_2
2. Affordability – including user benefits, considering residents
3. Traffic impacts – changes in traffic as a proxy for noise and safety/accidents, and for accessibility impacts through changes in journey times.

Table 2: Screening of Webtag impacts

Impact	Description of impact	Screening assessment	
		CAZ 1	CASAP
Air quality	Change in NO_2 concentration	There will be changes in concentrations across the city and for different user groups in these locations.	There will be changes in concentrations across the city and for different user groups in these locations.
Affordability and user benefits			
User benefits	Changes in vehicle operating costs met by the user Changes in incentives to encourage behaviour change.	Vehicle changes will be generated by this option and so there will be changes in operating costs (both positives and negative) In addition, direct financial incentives are provided to different user groups.	Rerouting of traffic might have an impact on access to key amenities with public transport, both positive and negative.
Affordability	Changes in user charges, including fares, tariffs and tolls;	Charging CAZ will have significant impact on costs which will vary by vehicle ownership	There will be no changes in fares or tolls.
Traffic and transport*			
Travel times	Changes in travel time	Possible distributional impacts where diversion affects generate changes in traffic and journey times on individual links	Redirecting the traffic will have both positive and negative impacts on bus journey times and car congestion.
Noise	Changes in noise levels – move in line with traffic on roads	Possible distributional impacts where diversion affects generate changes in traffic on individual links	Redirecting the traffic will have both positive and negative impacts on noise levels from traffic.
Accidents	Changes in accident rates – move in line with traffic / speed on roads	Possible distributional impacts where diversion affects generate changes in traffic on individual links	Small changes in traffic flows related to environmental corridors and demand management may influence accident levels.
Security	Any change in public transport waiting/interchange facilities including pedestrian access expected to affect user perceptions of personal security.	Charging CAZ will not impact on security. Could be impacted if indirect impact on public transport provision	No changes are expected that would influence perception of security.
Severance	Introduction or removal of barriers to pedestrian movement, either through changes to road crossing provision, or through	CAZ will not impact on physical road crossings	Bus priority measures are included but these are not expected to contribute to severance.

	introduction of new public transport or road corridors.		
Accessibility	Changes in routings or timings of current public transport services, any changes to public transport provision, including routing, frequencies, waiting facilities (bus stops / rail stations) and rolling stock, or any indirect impacts on accessibility to services (e.g. demolition & re-location of a school).	The charging scheme is not expected to change public transport services or impact on physical access to services. It may impact on journey times on some routes which could affect accessibility by car or public transport but this is covered under the journey time impacts	CASAP scheme is not expected to change public transport services or impact on physical access to services.

Key

Impacts screened in

Impacts screened out

2.4 Approach to assessing impacts

The approach to appraising each of the impacts closely follows the methodology set out in the JAQU and supporting WebTAG guidance. Namely, the 'impact variables' (describing how the impacts vary or are distributed across a geographic area) are overlaid with the 'grouping variables' (describing how different societal groups are distributed across the same area).

In most cases the appraisal is then made on the basis of splitting both the grouping and impact variables into quintiles, and then judging whether the impact on a given population group is proportionate to the representation of that group in the wider population (this type of analysis is referred to as 'quintile analysis' throughout this document). Not all of the impacts need to be appraised for each grouping variable. **Error! Reference source not found.** indicates the impacts that should be appraised for each group.[2]

The overlay of impacts and groups was then undertaken on a LSOA basis. The geospatial boundaries of each LSOA are available to download as a shapefile from the Office for National Statistics.[3] The datasets collected describing the social characteristics were joined to the spatial representation of the LSOAs to allow geospatial analysis of the social characteristics using a Geographical Information System (GIS).

Table 3: Impact categories in scope

Group	Air quality	Affordability	Traffic impacts
Deprivation / income	✓	✓	✓
Children	✓		✓
Old people			✓
Disability			✓
Sex			✓
Ethnicity			✓

In order to assess the impacts of the policy option on the population, a number of datasets were obtained to identify the social characteristics of the population within the study area. These datasets provided information on several characteristics at the LSOA level. A description of the characteristics obtained and their data source is provided Table 4 below:

Table 4: Key data sources

Dataset	Description
Income - Welsh Index of Multiple Deprivation (WIMD)	The WIMD gives an indication of the overall levels of deprivation in each LSOA and takes into consideration several factors including crime and employment deprivation. Lower IMD values correspond to areas with higher deprivation. This data is available from the Statistics of Wales: Welsh Indices of Deprivation 2014. Ranking in Wales.
Number of businesses	The number of businesses located in each MSOA are available, where a larger number represents a greater

[2] We present some summary results also for air quality impacts for old, disability, sex, ethnicity and elderlies, but these are not as detailed as for the children and income groups.
[3] http://geoportal.statistics.gov.uk/datasets/lower-layer-super-output-areas-december-2011-full-extent-boundaries-in-england-and-wales

	number of businesses located within the MSOA in question. This data is available from the Office for National Statistics nomis website, from the 2011 census data (UK Business Counts – local units by industry and employment band size (micro, small and medium count)). Ranking in England and Wales.
Number of children, elderly and data on gender	The number of individuals of each individual age, split by gender, are available for each LSOA. The larger values for this characteristic represent a larger number of individuals of this characteristic in the total population. This data was available from the Office of National Statistics (Table SAPE19DT1: Mid-2016 Population Estimates for Lower Layer Super Output Areas in England and Wales by Single Year of Age and Sex). The data for 2016 was the most recent population data set available at the time of writing. The number of children was identified as the sum of those aged 16 or below, while the number of elderly was identified the sum of those aged 65 or over. The proportion of females was identified by dividing the number of females in the population by the total population in each LSOA. Ranking in England and Wales.
Disability	The Health Deprivation and Disability index contains 4 indicators Limiting Long-Term Illness, indicator on All Cause Death Rate, The indicator on Cancer Incidence, The indicator on Low Birth Weight . This information is gathered from StatsWales and a higher value indicates a higher level of deprivation. This data is available from the Statistics of Wales: Welsh Indices of Deprivation 2014. Ranking in Wales
Ethnicity	The ratio of the number of non-white to white individuals in each LSOA was calculated to obtain an estimate of ethnicity in the area. The larger the ratio the greater the number of non-white individuals in the population. The data on the number of individuals classifying themselves in each ethnic class was available from the Office for National Statistics nomis website (Table LC2101EW – Ethnic group by sex by age). Ranking in England and Wales.
Sensitive receptor data	Shapefiles showing the location of education establishments, hospitals and parks was obtained from OS Open Data. The location of community centres was obtained from OS Address Base Plus as this was not available through Open Data.
Traffic composition	Number of registered Light good vehicles (LGV's) registered in each area. Data taken from DVLA/DfT. Ranking in England and Wales.

Businesses	The location (post codes) of businesses with HGV operator licences was obtained from data.gov.uk (Traffic Commissioners: goods and public service vehicle operator license records). Last updated Sept 2014.

In some cases, we have also produced alternative output metrics to help further explore and present the distributional nature of some of the impacts. For example, alongside the 'quintile analysis' for air quality, we also produce average changes in concentration by grouping variable quintile and present the average changes in concentration at sensitive receptors. Table 6 sets out the appraisal approach for each of the impacts screened-in.

2.5 Defining the assessment domains

The full assessment domain for the distributional analysis needs to consider all those who would likely be affected by the scheme. In addition to the full domain the assessment of the air quality impacts can only be carried out over the area for which the air quality modelling has been done, which is essentially the city boundary.

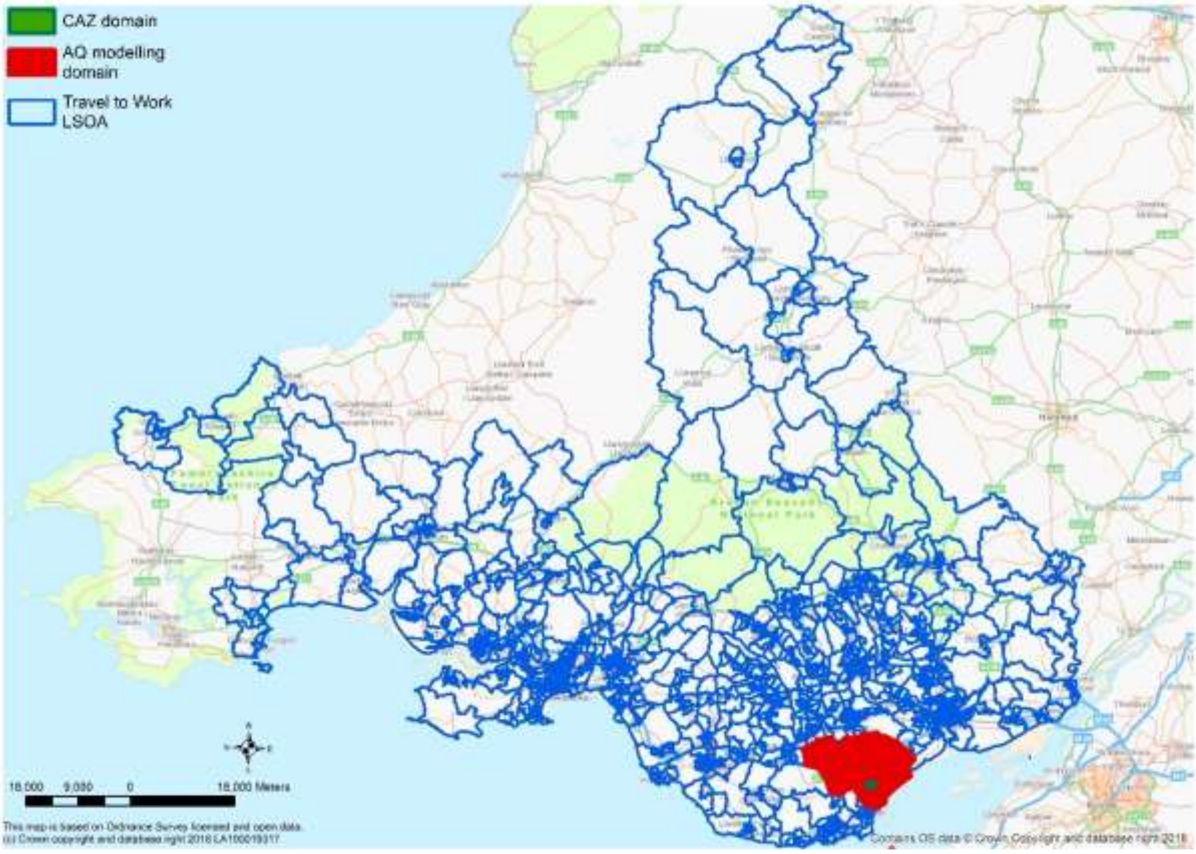
The study domain developed for this study is designed to capture the majority of those who would be impacted by the introduction of a charging scheme in the city centre, based on estimating a Cardiff Travel to Work area. This analysis was conducted using 2011 Office for National Statistics (ONS) census data at Middle Layer Super Output Area (MSOA). The Cardiff travel to work (TTW) area was assessed using data of residents in each MSOA who drive a car or van to work in the Cardiff CAZ area[4]. A practical definition of the extent of the travel to work area was then based on the top 5% of MSOA within Wales, where residents drive a car or van to work in Cardiff centre. MSOAs outside Wales have been excluded from the study as some variables (such as Income) are only available for Wales. The selected MSOA nevertheless covers over 97% for the residents commuting by car or van to Cardiff CAZ area.

As discussed in Section **Error! Reference source not found.** the social characteristics were available at the LSOA level, which is more spatially detailed. Therefore, the boundary of the distributional analysis domain identified from the MSOA commuters was used to identify the LSOA within the same domain. **Error! Reference source not found.** shows the LSOAs contained within the Travel to Work area (defined as DA domain for the rest of the study). **Error! Reference source not found.** also shows the location of the DA Domain in relation to air quality modelling domain, over which the air quality impact assessment is carried out, and the proposed Cardiff charging access restriction boundary for considering effects inside and outside this boundary.

The social characteristics data were available at LSOA level. Therefore, the boundary of the distributional analysis domain identified from the MSOA commuters was used to identify the LSOAs within the same domain in Geographical Information System (GIS) by selecting those LSOAs that fell within the domain extents.

[4] Location of usual residence and place of work by method of travel to work (MSOA level), Available from: https://www.nomisweb.co.uk/census/2011/wu03ew

Figure 1: Location of LSOAs included in geographical scope of distributional analysis. Also shown is the location of the air quality modelling domain, and the area within Cardiff covered by the Charging Scheme



2.6 Distribution of impact categories across the assessment domains

Six socioeconomic impact groups, as defined by the JAQU guidance, have been analysed in this distributional analysis and ranked as quintiles, with the first quintile meaning the lowest 20% and the fifth quintile the highest 20%of the population. The quintile ranking was based on the whole of Wales or England and Wales, depending on the variable (see Table 5). In addition, IMD category, used as reference for the income, has also been evaluated in relation to our study area only (DA Domain). All the socioeconomic impact groups are summarised as follows:

Table 5: Socioeconomic impact groups

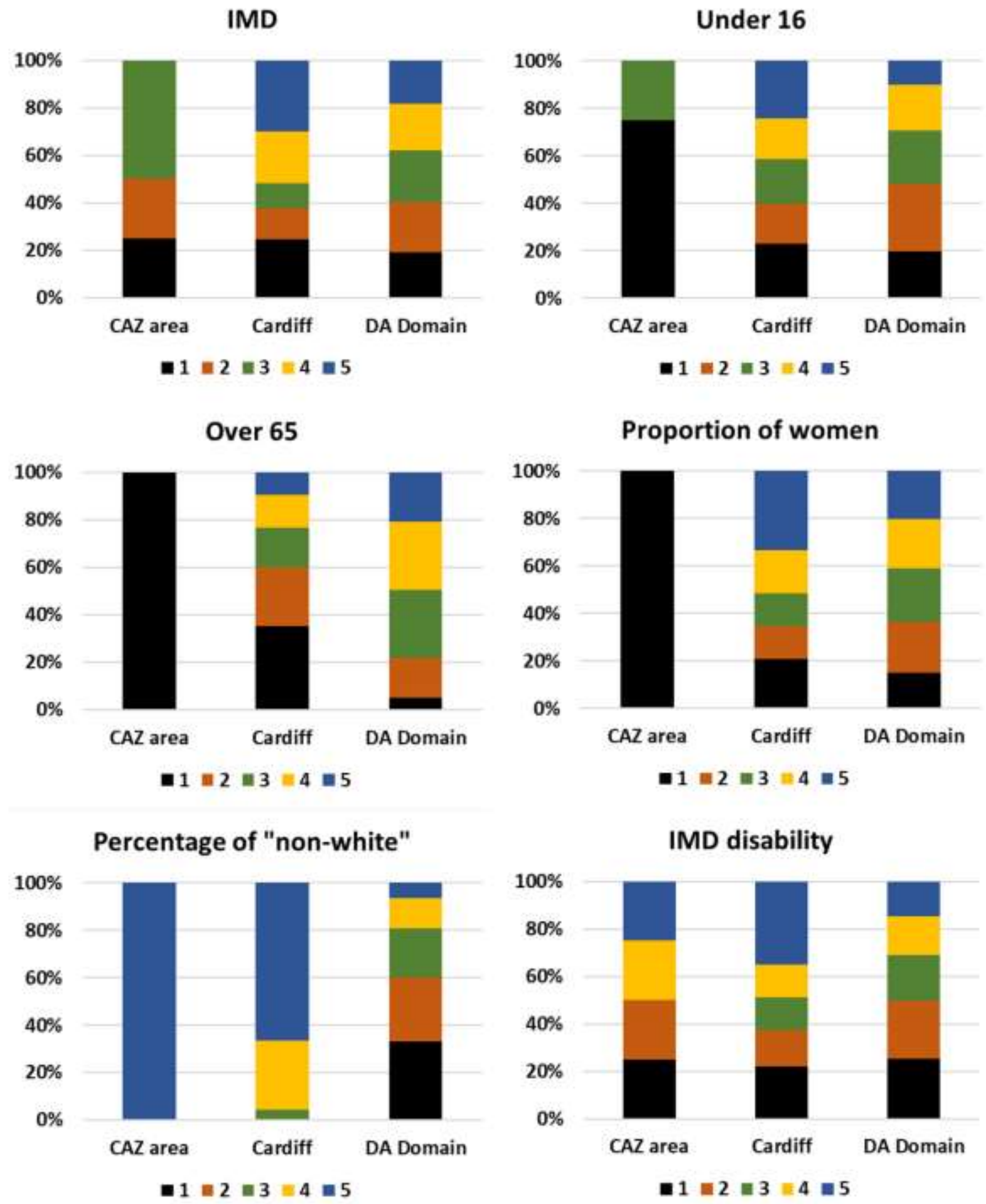
Socioeconomic group	Domain of study for quintile calculations	Quintile 1 reference	Quintile 5 reference
Income (referred to as IMD)	DA Domain Wales	Most deprived population	Least deprived population
Under 16 (referred to as Children)	England and Wales	Lowest proportion of under 16 in the population	Highest proportion of under 16 in the population
Over 65 (referred to as Elderly)	England and Wales	Lowest proportion of over 65 in the population (at LSOA level)	Highest proportion of under 65 in the population (at LSOA level)
Proportion of women (referred to as women)	England and Wales	Lowest proportion of women in the	Highest proportion of women in the

		population (at LSOA level)	population (at LSOA level)
Percentage of "non-white" (referred to as Ethnicity)	England and Wales	Lowest proportion of "non-white" in the population (at LSOA level)	Highest proportion of "non-white" in the population (at LSOA level)
IMD disability (referred to as disability)	Wales	Lowest ratio of population with disability in the population (at LSOA level)	Highest ratio of population with disability in the population (at LSOA level)

The quintile distribution for each impact group living within each of the assessment domains (DA Domain, AQ modelling domain and charging scheme areas) is summarised in Figure 2. Some of the key points from these charts can be summarised as follows:

- The city centre area (within the Charging Scheme boundary) has the highest proportion of low income families (only the first three quintiles of deprivation are found in this area), the lowest proportion of children under 16 and adults over 65. As such improvements in air quality in this area will have greater benefits for these lower income groups groups.
- Conversely the wider DA Domain the distribution among the different socioeconomic group is fairly distributed.
- The city centre also seems to have only the highest quintile of "non-white" population and lowest quintile of "women". But only 4 LSOAs are included within this area.
- More generally the distribution of these socioeconomic groups is more even outside the centre and in the DA Domain.

Figure 2 - Relative percentage of quintiles for each geographical zones and demographic groups. The total number of LSOAs within the different zones are as follows: 4 (CAZ area); 210 (Cardiff with CAZ area excluded); 1129 (DA Domain with Cardiff excluded)



Note that the quintile for IMD is for the DA domain

More detailed maps illustrating the quintile distribution for income (for the travel to work domain) and children under 16 are shown in Figure 3 and Figure 4. These maps highlight again that the city centre is dominated by the lowest quintile for IMD and a low proportion of children living within and close to the city centre. Mapped results for the other socioeconomic groups are presented in Appendix 1.

Figure 3: Quintile plots of Income (DA domain)

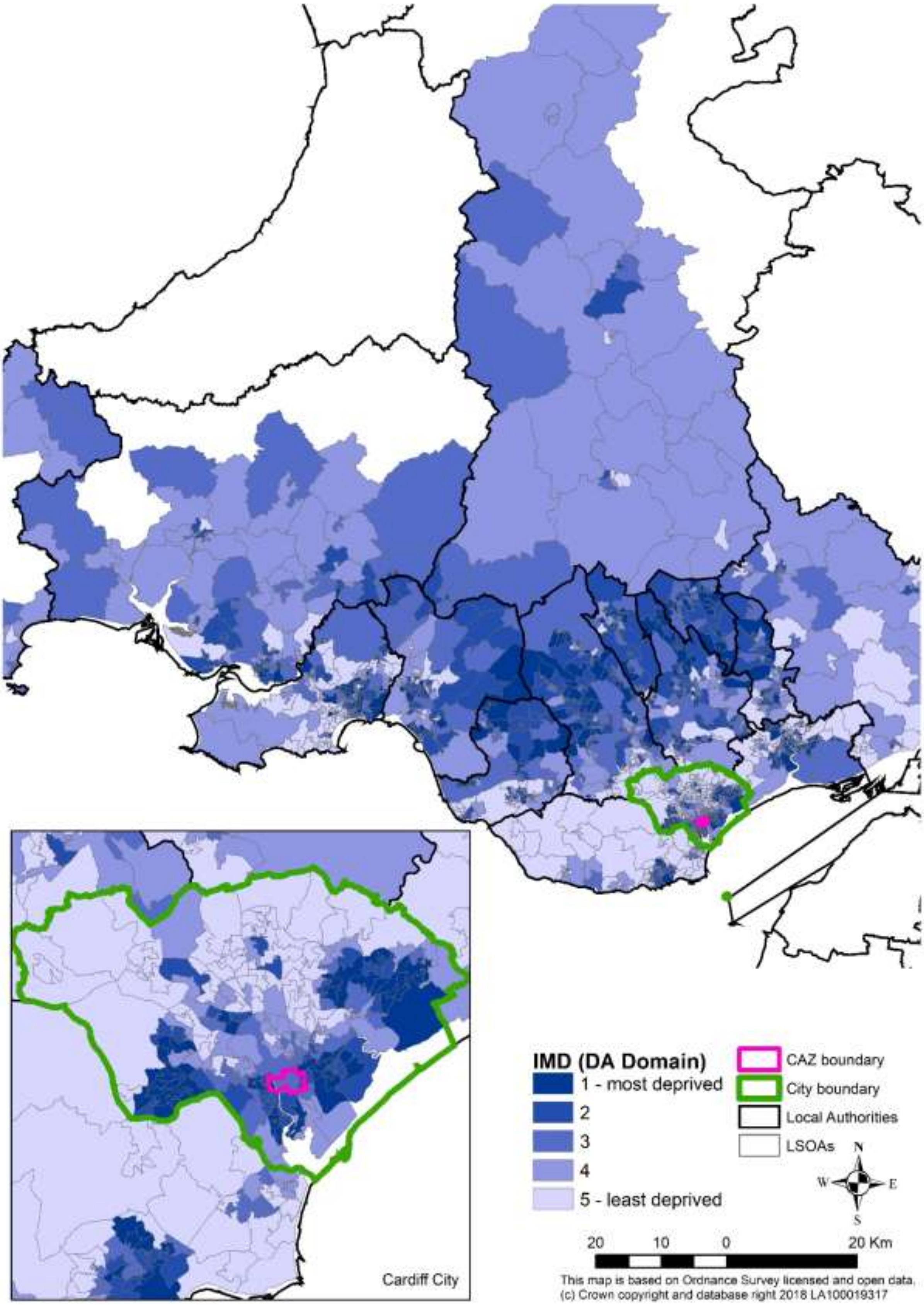
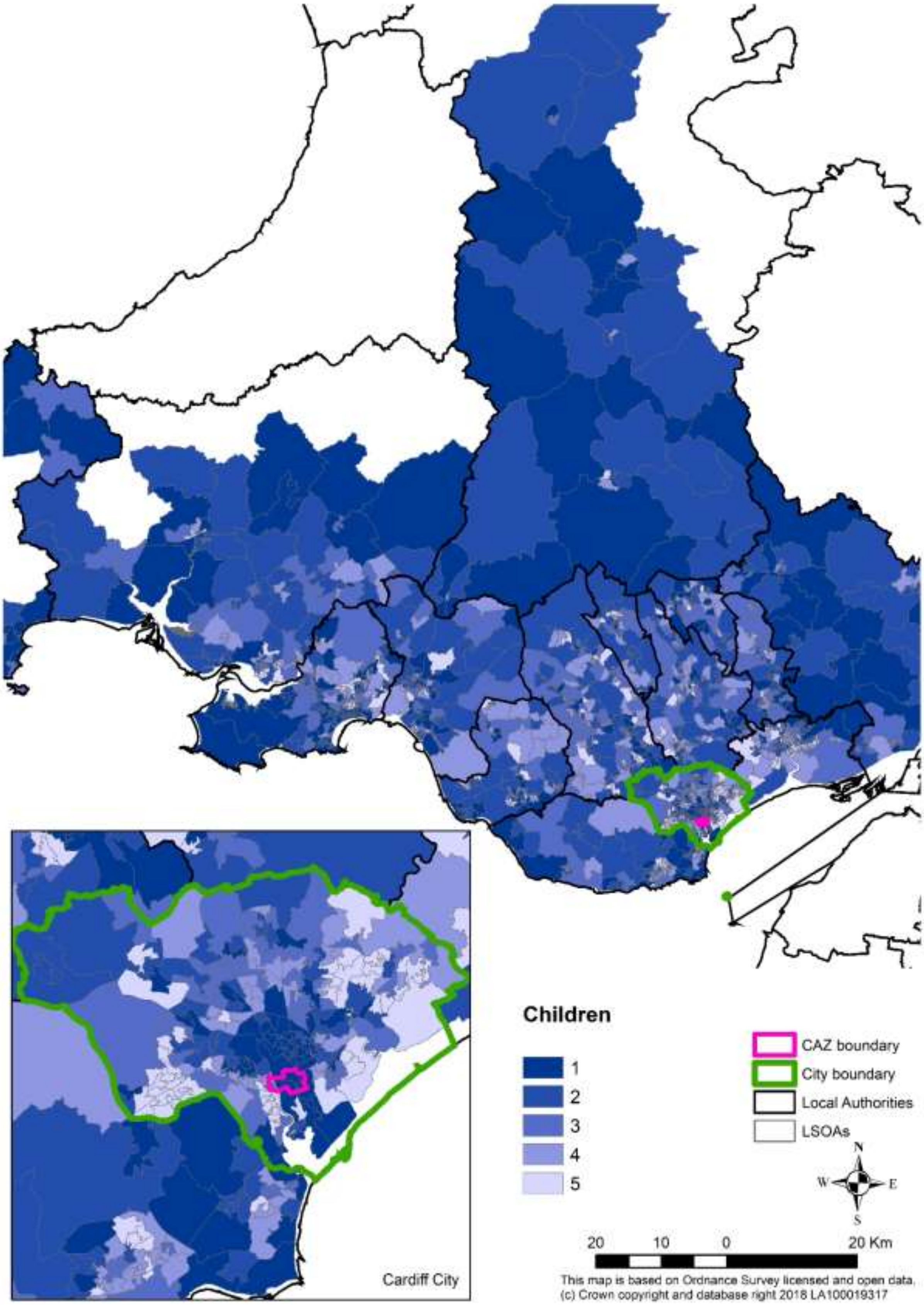


Figure 4: Quintile plots of Children (England and Wales)



Implicitly, the distributional analysis of the impacts considers the full lifetime over which they are due to be experienced. For some impacts, the focus of this assessment is on target year (e.g. air quality). This is because the assessment is limited due to the modelling available (e.g. outputs of the AQ model are only available for a limited number of years, and certainly not for the full appraisal period considered in the core CBA). However, the first year of the CAZ is also when CAZ impacts are expected to be greatest – hence this focus is useful to highlight the point at which most extreme distributional impacts are anticipated. Also, the further into the future the appraisal goes, the greater the uncertainty regarding both the impacts assessed, but also the distribution of the demographic groups within society.

Table 6: Appraisal approach for each impact

Impact	Proposed Method	Notes	Outputs
Air quality	• Overlay NO_2 concentrations (from supporting air quality modelling) with population data to calculate change in population-weighted concentrations[5] • Concentrations will be produced for weighted household centroid for each LSOA • Overlay mapping of concentrations with mapping of different groups at LSOA level • Groups covered: deprivation/income and children • Calculate average change in concentration by IMD / average children per household quintile • Calculate change in population weighted concentrations at sensitive receptors: Schools, Playgrounds, Parks, Hospitals, Care homes, Community centres • Quintile analysis for up/down changes	• Concentrations will be produced for weighted household centroid for each LSOA given resource / time required to model all household receptors •	• Average change in concentration by income decile / quintile of households with children • Count of LSOA and average change in concentration for those experiencing improving and worsening air quality, split by income decile / quintile of households with children • Average change in concentration at sensitive receptors • Quintile analysis (as described in Webtag)
Affordability for households	• Mapping of non-compliant vehicle ownership data for the core travel to Cardiff assessment area. • IMD is the only characteristic to be explored and will be overplayed with ownership data	• Cost / user benefit data is not available split spatially by LSOA to do a detailed analysis.	• Key risks and opportunities faced by non-charging measures • Count of non-compliant vehicles by LSOA • Overlay with travel to Cardiff and IMD quintiles
Traffic impacts - Noise / safety	• Map changes in AADT by road link and average for each LSOA • Overlay with impact groups	• Specific noise / accident modelling is not available. Use traffic patterns as a proxy	• Proportion of links/LSOA experience increases in traffic flows • Count of links experiencing significant change in traffic for each income decile / other characteristics • Quintile analysis as per JAQU guidance
Traffic impacts - Accessibility	• Calculate change in total journey time across network for each scheme. • Calculate change in journey time between each traffic model zone and the city centre. • Overlay with impact variables	• Journey time is used as a proxy for accessibility	• Change in total travel time for each scheme. • Count of traffic model zones where travel time increases / decreases split by characteristic • Quintile analysis

[5] Air quality modelling will be drawn from wider modelling around the CAZ options. Hence domain of distributional analysis will match that of wider AQ modelling. This will cover intervention area and surrounding area to capture potential diversionary routes

3 Air quality appraisal

3.1 Overlay with demographic groups

The Air Quality model carried out to evaluate the scenarios modelled the annual mean NO_2 concentrations across Cardiff, for modelling year 2021. All analysis presented here was undertaken on the model outputs for year 2021. All impacts are presented as a change relative to the baseline 2021 scenario.

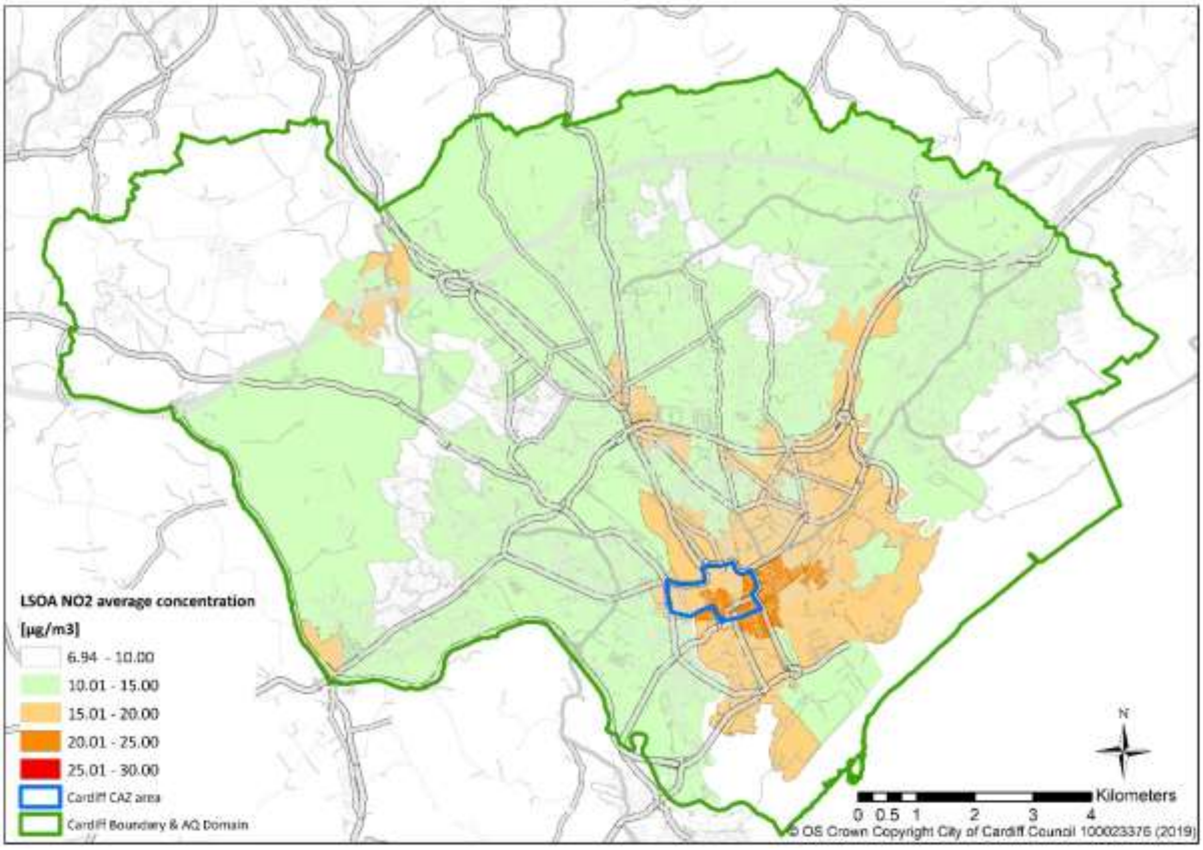
To assess the average NO_2 concentration for each LSOA falling within the air quality modelling domain in 2021 for the baseline and each of the modelled options, the calculation was carried out using the zonal statistics function in GIS. To evaluate the impact of the selected options on each LSOA with spatial resolution, the change in the NO_2 concentrations was calculated by subtracting the option from the 2021 Baseline (i.e. NO_2 concentrations without CAZ implementation). If the resulting change is *negative,* this means there is an *improvement* in air quality because of the introduction of the CAZ scheme.

Alongside the baseline, two scenarios were modelled:

1. CAZ 1 without additional measures
2. CASAP scenario

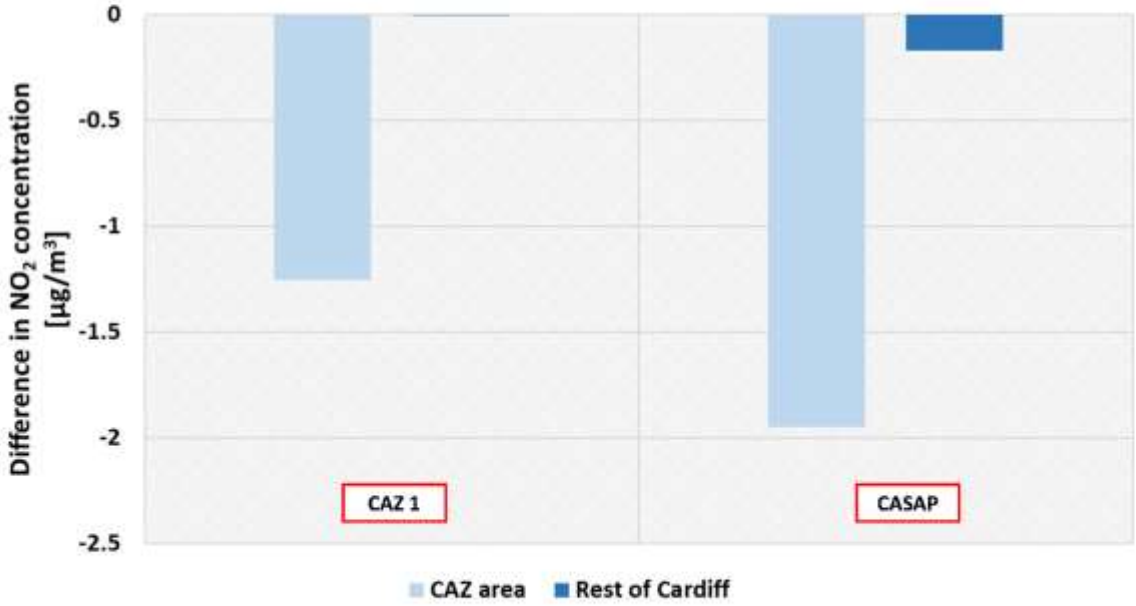
Only analysis regarding changes in NO_2 concentrations is presented in this section. Figure 7 shows high zones of concentration located in the city centre, for the modelled 2021 Baseline scenario. The highest NO_2 concentrations are mostly found in the city centre and the eastern area outside the centre.

Figure 5: Baseline 2021 NO_2 concentration at LSOA level for the AQ Domain (Cardiff)



The results of this analysis are summarised in Figure 6 below for each of our two analysis zones. This shows that the CASAP scenario has an overall stronger reduction in NO_2 concentration in comparison with the CAZ 1 scenario. Even within the charging scheme area, the CAZ 1 would appear not to be as effective as the CASAP option.

Figure 6 - Difference in average NO_2 concentration (in µg/m^3) between the modelled CAZ 1 and CASAP scenarios and the Baseline 2021 for two different geographical zones. This has been calculated from the AQ model outputs



From Figure 6 and Figure 8, the strongest air quality improvement is found within and near the CAZ area (especially North of the CAZ), for both scenarios. As previously discussed, the CASAP shows a stronger decrease in NO_2 concentration in the centre. In both scenarios, an increase in air pollution would occur in the northern part of the city, and this is more pronounced for the CAZ 1 scenario.

The greater improvement with the CASAP scenario could be due to the city-wide measures included in this scenario, namely bus and taxi fleet upgrade schemes. The traffic management schemes in the city centre also included in CASAP explain the stronger decrease in NO_2 concentrations modelled in the CAZ area.

Figure 7: Absolute Difference in NO_2 concentrations (in µg/m^3) averaged at LSOA, between the CAZ 1 and baseline scenario

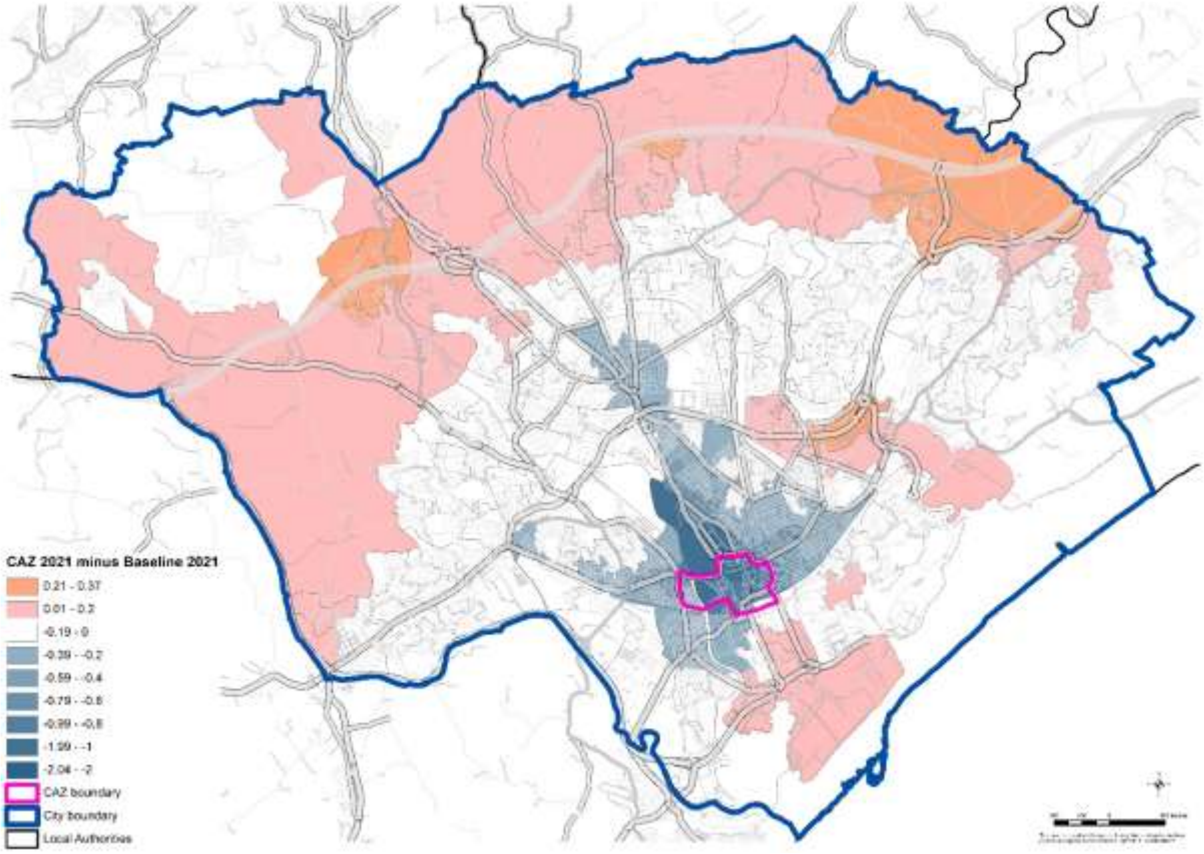
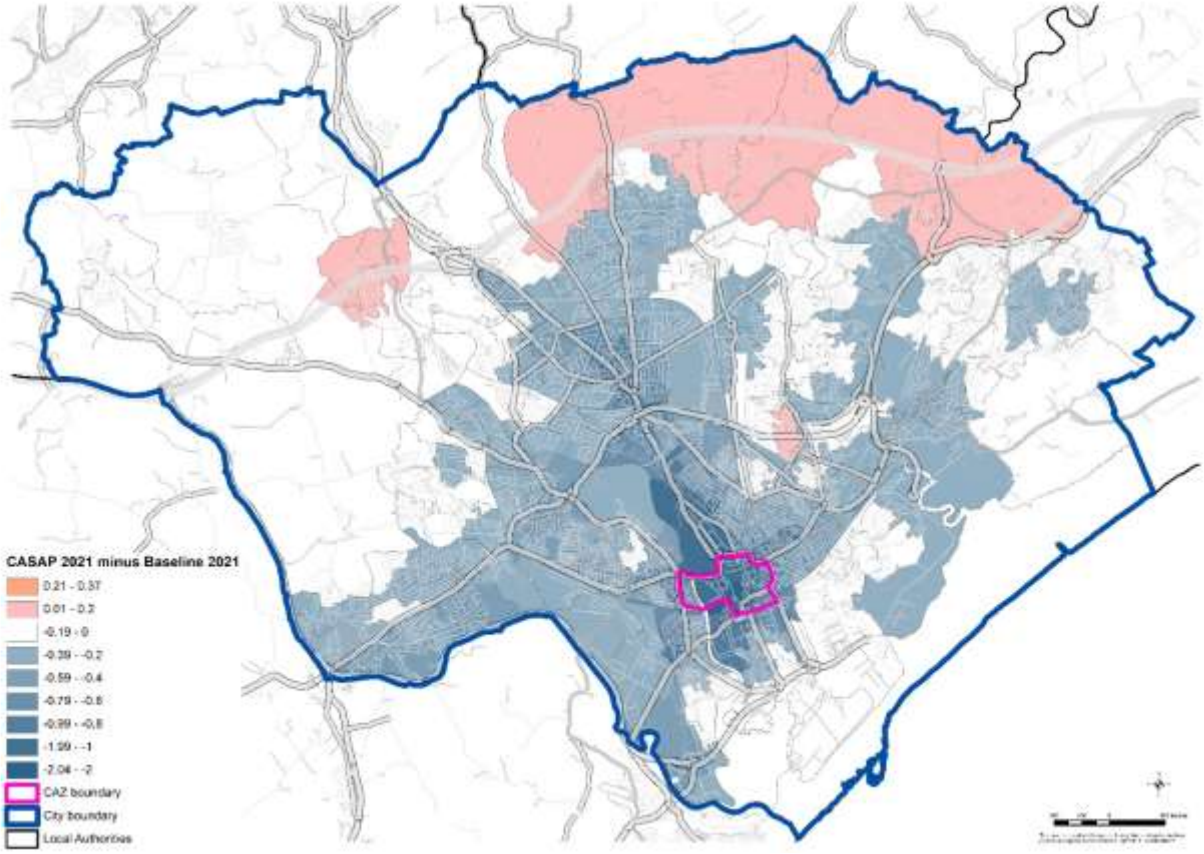


Figure 8: Absolute Difference in NO_2 concentrations (in µg/m³) averaged at LSOA, between the CASAP and baseline scenario



3.2 Socioeconomic quintile analysis

The following analysis explores the distribution of average NO_2 concentrations for each of our socioeconomic impact groups, with a focus on low income groups (WIMD) and children under 16.

Table 7: Modelled NO_2 concentration differentiated by IMD quintile (reference whole model domain) for the baseline, the CAZ 1 and CASAP scenarios

Option	Income IMD Quintile domain	Most deprived ← 1	2	3	4	Least deprived → 5
2021 BASELINE	Average NO_2 concentration (µg/m³)	13.00	13.50	14.30	13.40	11.81
2021 CAZ 1	Average NO_2 concentration (µg/m³)	12.87	13.35	14.09	13.29	11.80
	Absolute difference in NO_2 concentration to baseline (µg/m³)	-0.13	-0.15	-0.22	-0.11	-0.01
	Relative difference in NO_2 concentration to baseline (%)	-1.02	-1.12	-1.51	-0.83	-0.08
2021 CASAP	Average NO_2 concentration (µg/m³)	12.67	13.18	13.81	13.06	11.59
	Absolute difference in NO_2 concentration to baseline (µg/m³)	-0.33	-0.32	-0.49	-0.34	-0.22

	Relative difference in NO_2 concentration to baseline (%)	-2.54	-2.36	-3.42	-2.55	-1.90

For the baseline situation the analysis shows that concentration of NO_2 are lowest for the highest income groups indicating that these groups tend to live in areas with less traffic and congestion. Therefore, there is a clear existing inequality in the burden of air pollution in Cardiff when looking through the lens of income distribution. In addition, in the baseline, the areas with the lowest proportion of children have the highest levels of pollution.

The implementation of a CAZ 1 scheme will have a lower impact in terms of air quality (NO_2 concentrations) than the CASAP scenario. With the CAZ 1 scenario, all the quintiles for income and children will see on average a decrease in NO_2 concentrations, with the greatest improvement found for the middle income (quintile 3) and the areas with the lowest population of children.

With the implementation of the CASAP scenario, the distribution for both income and under 16 groups is similar but with a stronger decrease in NO_2 concentrations.

Table 8: Modelled NO_2 concentration differentiated by "Under 16s" quintile for the baseline and all the scenarios

Option	Under 16 (quintile)	Lowest proportion ← 1	2	3	4	Highest proportion → 5
2021 BASELINE	Average NO_2 ($\mu g/m^3$)	14.92	12.81	11.94	12.81	11.90
2021 CAZ 1	Average NO_2 concentration ($\mu g/m^3$)	14.70	12.75	11.92	12.69	11.83
	Absolute difference in NO_2 concentration to baseline ($\mu g/m^3$)	-0.22	-0.06	-0.02	-0.11	-0.07
	Relative difference in NO_2 concentration to baseline (%)	-1.48	-0.48	-0.21	-0.89	-0.60
2021 CASAP	Average NO_2 concentration ($\mu g/m^3$)	14.44	12.53	11.74	12.48	11.62
	Absolute difference in NO_2 concentration to BASELINE ($\mu g/m^3$)	-0.47	-0.28	-0.20	-0.32	-0.28
	Relative difference in NO_2 concentration to BASELINE (%)	-3.17	-2.17	-1.68	-2.52	-2.37

An alternative view of the data is seen by counting the number of LSOAs experiencing an improvement or a deterioration of air quality in terms of NO_2 and this is shown in Table 9 and Table 10 below.

The charging scheme improves air quality for the majority of the population within Cardiff, but a non-negligible part of the population will see its air quality deteriorate, mainly for the least deprived population (Table 9). This is most probably due to the diverting traffic increasing concentrations around the charging zone. In terms of the impact of the CASAP scenario on income quintiles the picture is similar to when considering average concentrations. The greatest benefit is for low income areas and the smallest benefit is for high income areas. In relation to children under 16 the picture is more complex. Both those in the highest and lowest quintiles have the greatest number of areas showing an improvement.

In those tables the impact of a CASAP scenario will be of higher benefit in terms of air quality improvement, in comparison with a CAZ 1 scenario.

Table 9: Number of LSOAs and population with an improvement or a deterioration of NO_2 concentration (relative to baseline), disaggregated by IMD quintile (reference whole model domain) for the domain of study

Option	Income IMD Quintile domain	Most deprived ← 1	2	3	4	Least deprived → 5
CAZ 1	Number of LSOAs with improved air quality	55	26	25	29	40
	Population with improved air quality	93,156	47,137	43,632	50,379	64,149
	Number of LSOAs with a worsening of air quality	4	0	2	7	26
	Population with a worsening of air quality	6677	0	3038	11117	42183
CASAP	Number of LSOAs with improved air quality	59	26	27	36	56
	Population with improved air quality	99,833	47,137	46,670	61,496	89,136
	Number of LSOAs with a worsening of air quality	0	0	0	0	10
	Population with a worsening of air quality	0	0	0	0	17,196

Table 10: Number of LSOAs and population with an improvement or a deterioration of NO_2 concentration (relative to baseline), disaggregated by "Under 16" quintile for the domain of study

Option	Under 16 Quintile domain	Lowest proportion ← 1	2	3	4	Highest proportion → 5
CAZ 1	Number of LSOAs with improved air quality	42	25	29	32	47
	Population with improved air quality	78,746	39,819	46,792	52,255	80,841
	Number of LSOAs with a worsening of air quality	9	10	12	4	4
	Population with a worsening of air quality	13543	15387	19344	7543	7198
CASAP	Number of LSOAs with improved air quality	50	33	38	34	49
	Population with improved air quality	90,304	51,949	61,366	56,151	84,502
	Number of LSOAs with a worsening of air quality	1	2	3	2	2

	Population with a worsening of air quality	1,985	3,257	4,770	3,647	3,537

3.3 Sensitive receptors

Sensitive receptors in Cardiff were divided into 11 categories as follows:

- CC04: Public and Village Halls
- CE02: Nursery/Creche
- CE03: Primary, Junior, Infants or Middle School
- CE04: Secondary School
- CM03: Medical, Hospitals and Hospices
- LP01: Public Parks and Gardens
- LP02: Public Open Spaces and Nature Reserves
- LP03: Playgrounds
- RI01: Care/Nursing Homes
- RI02: Communal Residences
- RI03: Residential Education

With the implementation of a CAZ 1 or a CASAP scenario, no categories of sensitive receptors see on average an increase in concentrations (Figure 9). For all categories of sensitive receptors, the CASAP option would lead to a stronger decrease in NO_2 concentrations than a CAZ 1.
For both scenarios, the strongest decrease in NO_2 concentrations is modelled for residential education centres and communal residences. As previously discussed, CAZ 1 would strongly improve air quality within the CAZ area but can deteriorate it elsewhere. Depending then on the location of the sensitive receptors, air pollution can be deteriorated if its location is outside the CAZ area. Residential education and communal residences are most likely found within the CAZ area, as shown in Figure 10.

Figure 9 - Difference in NO_2 concentration between the CAZ 1 and the Baseline 2021, disaggregated by the 11 groups of sensitive receptors

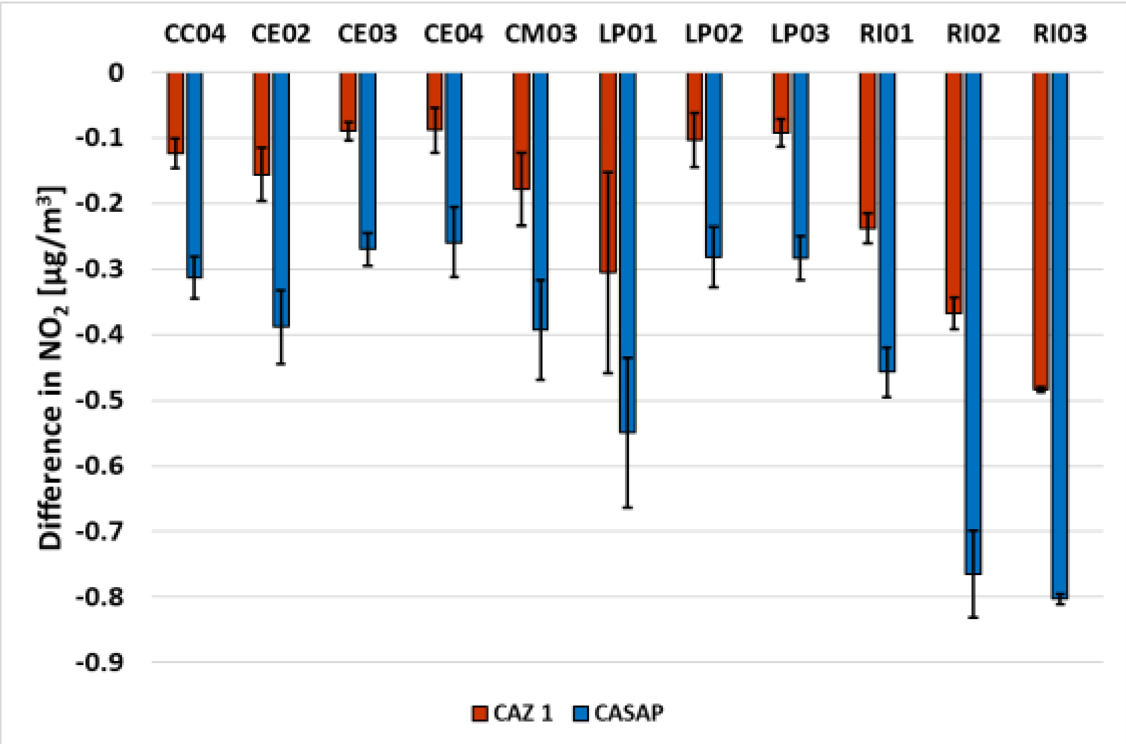
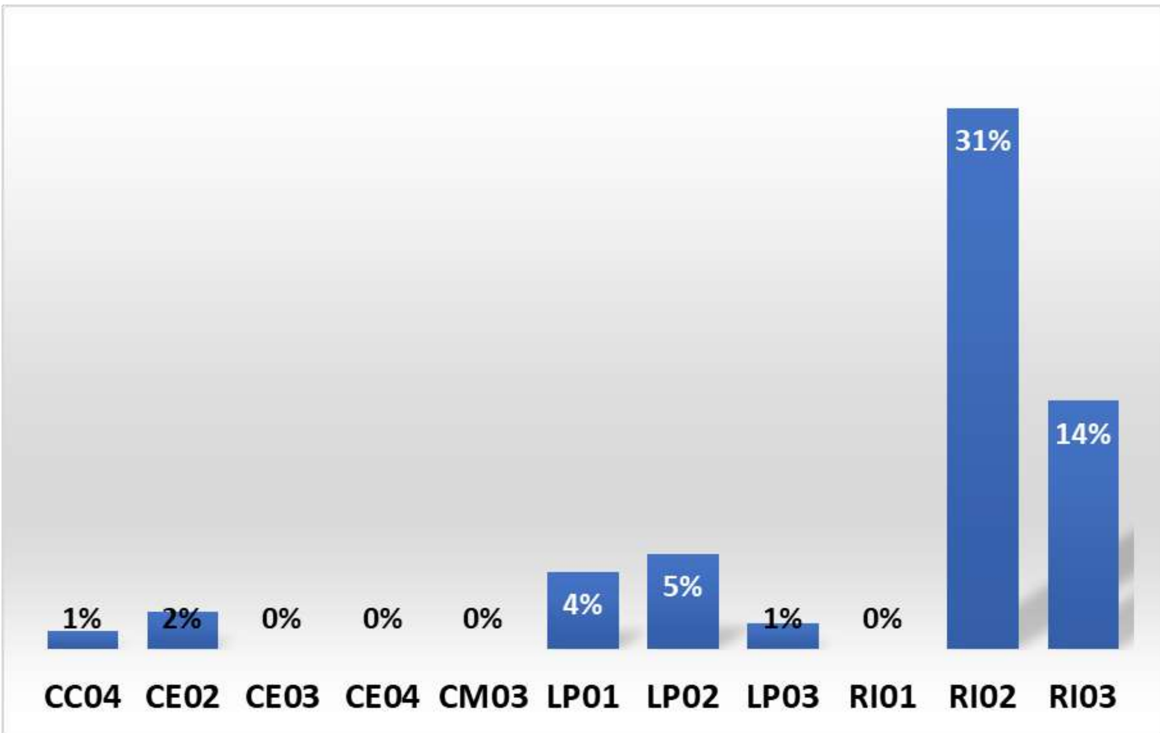


Figure 10 - Percentage of groups of receptors located in the CAZ area



3.4 Quintile distributional analysis

The overlay of the impact and demographic variables following the Webtag guidance for IMD is presented in **Error! Reference source not found.** and for the "under 16" category in Table 12 for the CAZ 1 scenario and Table 13 and Table 14 for CASAP. This is designed to show whether the proportion of those seeing a benefit for any given quintile if greater or less than the proportion of this quintile in the overall population. This indicates if any one quintile group is seeing a relative benefit or disbenefit, whereas the analysis on section 3.2 showed the total benefit or disbenefit for each social group.

The implementation of a charging scheme CAZ 1 would lead to a large share of the population with the lowest incomes as well as the areas with the highest proportion of children seeing improved air quality. As the proportion of the population "winning" from a CAZ option is higher than the share of total population in the impact area for those quintiles, this has been assessed as "Large beneficial" based on the Webtag definitions, i.e. the share of 'winners' in this group is grater that the share of this group in the overall population. On the other hand, the least deprived population as well as quintiles 2 and 3 of children is assessed as "slight beneficial" having a share of the total winners being similar to their overall share of the population.

Table 11: Webtag 'quintile' analysis for CAZ 1 – WIMD overlay with air quality

Income IMD	Most deprived	Least deprived	

CAZ 1	0%-20% 1	20%-40% 2	40%-60% 3	60%-80% 4	80%-100% 5	Total
Population with improved air quality	93,156	47,137	43,632	50,379	64,149	
Population with no changes[6]	0	0	0	0	0	
Population with deteriorating air quality	6,677	0	3,038	11,117	42,183	
Net winners/losers	86,479	47,137	40,594	39,262	21,966	
Total number of winners across all groups						235,438
Net winners/losers in each area	36.73%	20.02%	17.24%	16.68%	9.33%	
Share of the total population in the impact area	27.62%	13.04%	12.91%	17.01%	29.42%	
Assessment	✓✓✓	✓✓✓	✓✓	✓✓	✓	

Table 12: Webtag 'quintile' analysis for CAZ 1 – Children overlay with air quality

Under 16 CAZ 1	Lower proportion ← 0%-20% 1	20%-40% 2	40%-60% 3	60%-80% 4	Higher proportion → 80%-100% 5	Total
Population with improved air quality	78,746	39,819	46,792	52,255	80,841	
Population with no changes[7]	0	0	0	0	0	
Population with deteriorating air quality	13,543	15,387	19,344	7,543	7,198	
Net winners/losers	65,203	24,432	27,448	44,712	73,643	
Total number of winners across all groups						235,438
Net winners/losers in each area	27.69%	10.38%	11.66%	18.99%	31.28%	
Share of the total population in the impact area	25.53%	15.27%	18.30%	16.54%	24.36%	
Assessment	✓✓	✓	✓	✓✓	✓✓✓	

[6] For this category it has been assumed a difference in NO_2 concentration between the modelled CAZ scenario and the baseline to be 0.
[7] For this category it has been assumed a difference in NO_2 concentration between the modelled CAZ scenario and the baseline to be 0.

The implementation of a CASAP scenario would not lead to a socioeconomic group with a "Large beneficial" impact. This is due to a lower proportion of population that would see a worsening of air quality. So nearly everyone is a winner and this share of winners in each group is the same as the share of this group in the overall population. Overall, for both the income and under 16 groups, and almost all quintiles, the overall assessment is defined as "moderate beneficial". Only the least deprived population is considered as "slight beneficial", as only this category as some people would have an increase in NO_2 concentrations.

Table 13: Webtag 'quintile' analysis for CASAP – WIMD overlay with air quality

Income IMD	Most deprived ←				Least deprived →	Total
	0%-20%	20%-40%	40%-60%	60%-80%	80%-100%	
CASAP	1	2	3	4	5	
Population with improved air quality	99,833	47,137	46,670	61,496	89,136	
Population with no changes[8]	0	0	0	0	0	
Population with deteriorating air quality	0	0	0	0	17,196	
Net winners/losers	99,833	47,137	46,670	61,496	71,940	
Total number of winners across all groups						327,076
Net winners/losers in each area	30.52%	14.41%	14.27%	18.80%	21.99%	
Share of the total population in the impact area	27.62%	13.04%	12.91%	17.01%	29.42%	
Assessment	✓✓	✓✓	✓✓	✓✓	✓	

Table 14: Webtag 'quintile' analysis for CASAP – Children overlay with air quality

Under 16	Lower proportion ←				Higher proportion →	Total
	0%-20%	20%-40%	40%-60%	60%-80%	80%-100%	
CASAP	1	2	3	4	5	
Population with improved air quality	90,304	51,949	61,366	56,151	84,502	
Population with no changes[9]	0	0	0	0	0	

[8] For this category it has been assumed a difference in NO_2 concentration between the modelled CAZ scenario and the baseline to be 0.
[9] For this category it has been assumed a difference in NO_2 concentration between the modelled CAZ scenario and the baseline to be 0.

Population with deteriorating air quality	1,985	3,257	4,770	3,647	3,537	
Net winners/losers	88,319	48,692	56,596	52,504	80,965	
Total number of winners across all groups						327,076
Net winners/losers in each area	27.00%	14.89%	17.30%	16.05%	24.75%	
Share of the total population in the impact area	25.53%	15.27%	18.30%	16.54%	24.36%	
Assessment	✓✓	✓✓	✓✓	✓✓	✓✓	

3.5 Summary

The geographical distribution of changes in NO_2 concentrations show a similar distribution between the options. In simple terms both scenarios will lead to an overall improvement in air quality, more pronounced with the CASAP option than CAZ 1. The strongest decrease is expected to be located in the city centre, but a small deterioration would occur in the northern part of the city.

The analysis in relation to demographic data at the LSOA level reflects this basic picture and allows an assessment of the distribution of impacts for key socioeconomic groups (primarily IMD and children under 16). Again, the distribution appears to be similar with the CASAP and CAZ 1 options, but with a stronger effect for the CASAP scenario. That said, the most deprived part of the population as well as the population with the highest proportion of children (representative of the residents inside the CAZ area and the city centre to some extent) would have the most air quality improvement with both scenarios.

Looking at sensitive receptors, again, both scenarios would lead on average to a reduction in NO_2 concentrations, but more pronounced with a CASAP scenario. The highest reduction is expected to be experienced for residential education and communal residences, as mostly found within the CAZ area and the city centre.

Overall, both scenarios lead to an improvement in air quality for all quintiles of the income and under 16 socioeconomic groups, and therefore no negative distributional impact. The highest income of the population will disbenefit the most from a CAZ 1.

Table 15: Summary of air quality distributional impacts

Scenario	Summary assessment
CAZ 1	✓ • All LSOAs see improvement in air quality concentrations, hence quintile analysis shows no distributional impact. • A stronger benefit is found for areas with the lowest income. However, the highest income would be disadvantaged. • Option achieves on average reduction at all sensitive receptors
CASAP	✓✓ • All LSOAs see improvement in air quality concentrations, hence quintile analysis shows no distributional impact • A stronger benefit is found for areas with the lowest income • Option achieves on average reduction at all sensitive receptors

4 Affordability for households

4.1 Impact of the policy options

Expected direct and indirect impacts on households are explored in Table 16 and Table 17. These tables assume that residents are primarily concerned with those policy options that impact on cars and consumer goods and services.

The CASAP scenario, which includes traffic management schemes, may have a negative impact on a household if their journeys are directly impacted by the scheme and as a result suffer increased travel times, route changes or opt to change mode. Similar impacts of the scheme on goods delivery may have an indirect impact on the cost/convenience of consumer goods and services.

The charging scheme is mandatory for all non-compliant vehicles (in this case passenger cars) and therefore imposes a direct impact on households. Indirect impacts are also likely to be more pervasive under the charging scheme as direct impacts on businesses are more certain.

Table 16: Relevant policy options for households and their direct impacts

	CASAP	CAZ 1
Relevant measures for Cars	Changes to traffic management: West Gate, East side and Castle street schemes	£10/day
Direct impacts on Cars	Potential travel time increase from delay/diversion (↓- 4)	Cost added to the OPEX of non-compliant vehicles. (↓ - 5)

Net Impact - ↑ = minor positive impact, ↑↑ = positive impact, ↓ = minor negative impact, ↓↓ = negative impact ↑/↓ = mixed impact.
Confidence - 1-5 = low confidence – certainty.

Table 17: Relevant policy options for households and their indirect impacts

	CASAP	CAZ 1
Commuting	Workforce may experience travel time increases of change mode in response to scheme. (↓ - 3)	Employees may be charged for commuting. May have impacts on car sharing and commuting patterns which could lead to increased commuting time and loss of welfare. (↑/↓ - 2)
Cost of goods and services	Consumer goods may increase in price if delivery delays occur (↓ - 1)	Reduction in resale values of vehicles (↓ - 2)

Net Impact - ↑ = minor positive impact, ↑↑ = positive impact, ↓ = minor negative impact, ↓↓ = negative impact ↑/↓ = mixed impact.
Confidence - 1-5 = low confidence – certainty.

4.2 Distribution of households and car ownership

A charging scheme will directly impact on households with cars that do not comply with the CAZ standard and so would be subject to a charge or the cost of upgrading their vehicle. Therefore, low income groups could be more impacted as they are more likely to own older non-compliant vehicles (Table 18).

The direct impacts with a CAZ 1 on affordability for households have been analysed in further detail. The distributional impact of these costs will depend on the ownership profile of non-compliant vehicles.

Distributional analysis was undertaken by combining two parameters available at LSOA level which will drive the costs faced by households:

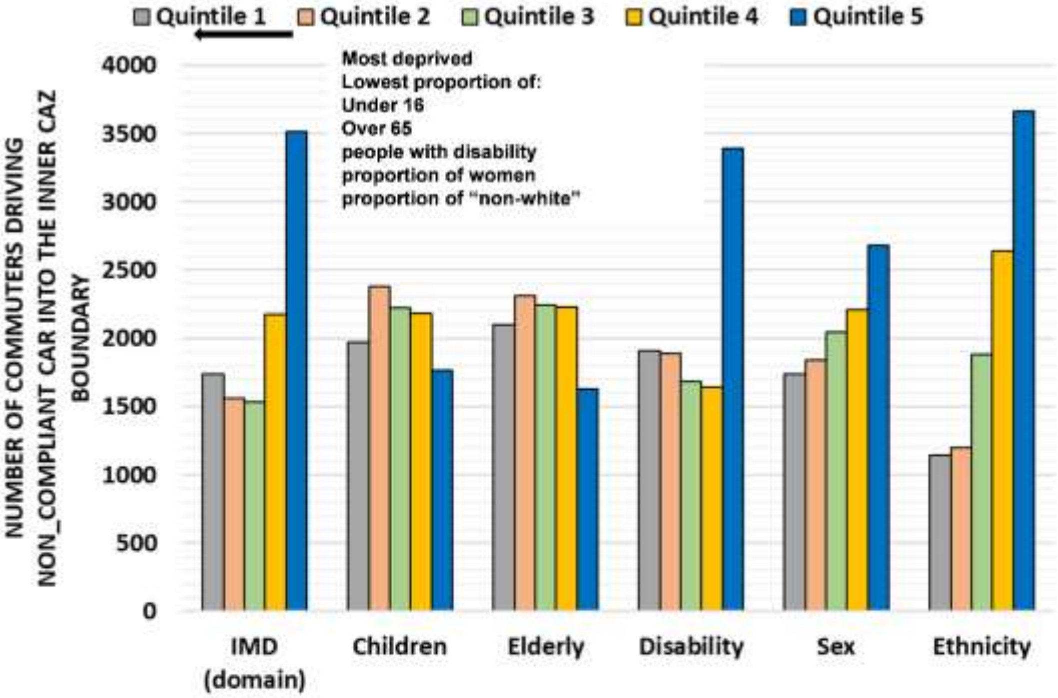
1. Ownership of non-compliant vehicles
2. Proportion of persons driving a car to work within the inner CAZ boundary.

To account for travelling to the CAZ, 2011 Census data was used. This data describes the drivers that are driving with a car to the CAZ boundary. It has then been averaged for each MSOA and then LSOA. There are several caveats that should be noted in using this census data:

- only commuters are considered in this dataset, so the data does not represent all trips to the CAZ;
- data is only available at MSOA level, hence the number of trips into the CAZ Inner boundary were disaggregated to LSOA of origin;
- Data is from 2011.

Using the JAQU data for registered non-compliant cars at LSOA level for England and Wales, the percentage of non-compliant cars have been multiplied by the number of trips to the CAZ boundary for each LSOA of the “DA Domain”. The result is an estimate of the number of drivers using non-compliant cars and going to the CAZ (**Error! Reference source not found.**) from each LSOA, which is then a proxy of the likely cost burden of the CAZ falling on each LSOA.

Figure 11: Average daily trips of commuters from the "DA Domain" to the CAZ 1 boundary with non-compliant cars



Notes: disaggregated by quintiles of demographic groups.

The highest number of estimated non-compliant trips are performed by (and hence the costs of the CAZ scheme fall greatest upon) the least deprived population (quintile 5 of IMD). Costs then decrease for the remaining quintiles. Despite that a greater proportion of non-compliant vehicles are owned by poorer population (see **Error! Reference source not found.**), the costs likely to be more important for the richer population, as they make more trips to the CAZ.

Table 18: % of cars non-compliant split by IMD quintile

IMD quintile	1	2	3	4	5
% cars owned by households in quintile which are NC	50.0	48.5	47.8	48.6	42.9

This result matches evidence from the literature: studies[10] note that in general, there is a negative relationship between car age and household income (i.e. older cars tend to be owned by poorer households). Although it is not reflected by the number of drivers going to the CAZ 1.

[10] See for example: http://economics.ca/2009/papers/0455.pdf

Figure 12: Number of drivers commuting with non-compliant cars to the CAZ 1 area, averaged at LSOA level

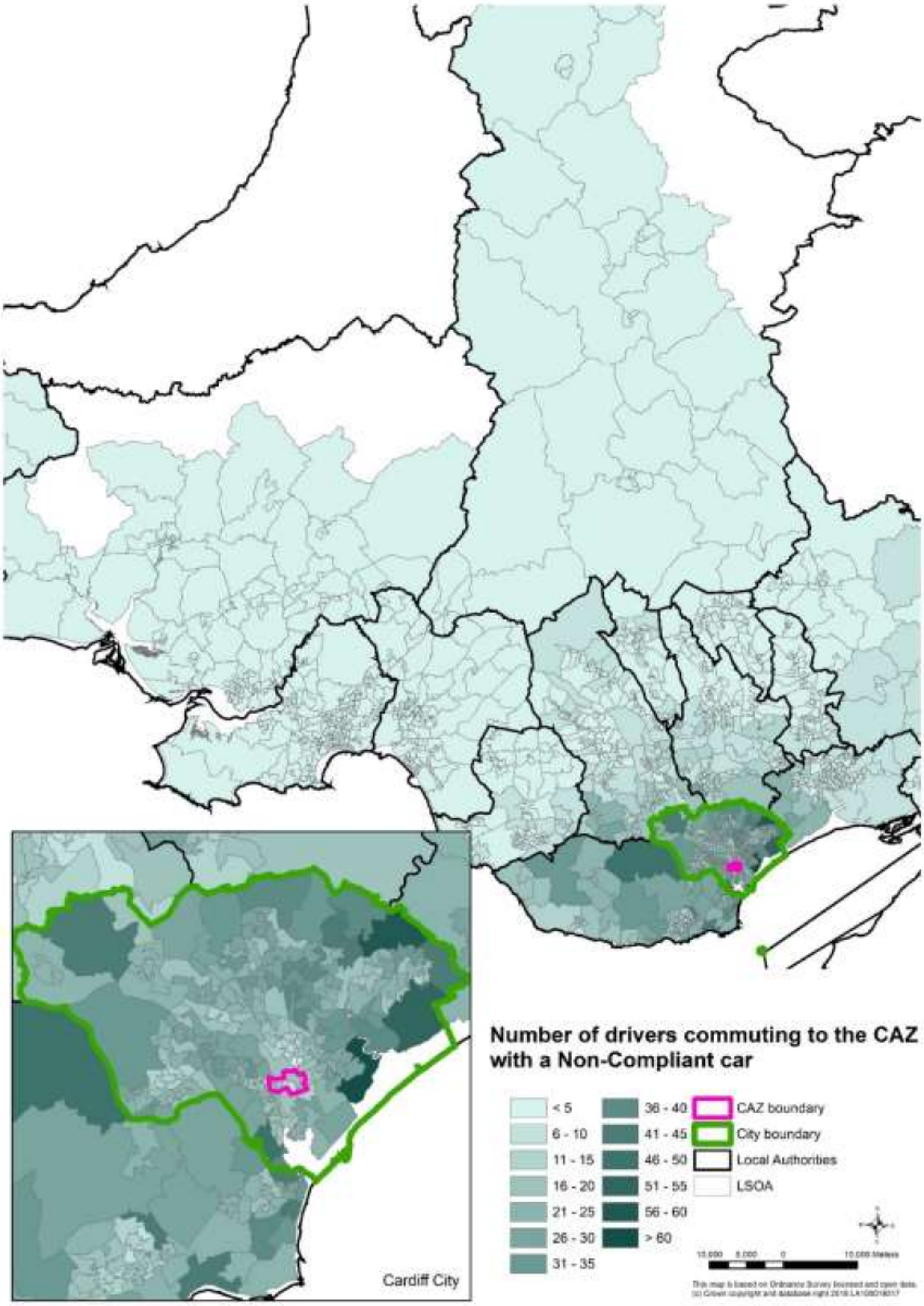


Figure 12 highlights that most of the drivers commuting to the CAZ live in the Vale of Glamorgan County. Based on the maps shown in the Appendix, this is an area with a majority of quintiles 5 for WIMD. Furthermore, the costs of the CAZ are likely to be higher for: the highest ratio of "non-white" population, the highest ratio of persons with disabilities as well as the highest proportion of women. This is again driven by the origin of those trips, mostly in the Vale of Glamorgan County. No significant trends could be observed relative to the children or elderly demographic variables.

Most trips to the CAZ (with non-compliant cars) do not originate from within the CAZ boundary itself (Figure 12) – this is a key feature in the pattern of results. The size of the impacts on different groups reflects the demography of those living in the South Western part outside of the city. A behavioural change from the city centre residents is expected with the implementation of a CAZ 1 which will limit the impact of the CAZ on these residents. Affected residents will in theory adopt a least-cost response: a decrease in travelling with cars, acquisition of a compliant car to still be able to drive in the centre. These modifications could bias the results presented but cannot can be quantified in the scope of this study.

The webtag "quintile" analysis (**Error! Reference source not found.**) highlights again that the least deprived quintile of the population is likely to suffer the most from a CAZ 1. However, given some level of costs fall on all LSOAs in the scope of the DA Domain (i.e. all LSOAs have some non-compliant vehicles and some trips to the CAZ), all LSOAs (and hence all their residents) fall within the 'losers' category. The assessment presented corresponds to the "Moderate Adverse" group for each quintile. No assessment is presented for the other options given these options will not have direct effects on households in the same way as the impacts analysed here.

Table 19: Webtag 'quintile' analysis for CAZ B Reduced Boundary – IMD overlay with "number of trips with non-compliant cars"

Income IMD CAZ 1	Most deprived ← 0%-20% 1	20%-40% 2	40%-60% 3	60%-80% 4	Least deprived → 80%-100% 5	Total
Number of population non driving non-compliant cars to the CAZ	0	0	0	0	0	
Number of population driving non-compliant cars to the CAZ	1,737	1,562	1,536	2,172	3,511	
Net winners/losers	-1,737	-1,562	-1,536	-2,172	-3,511	
Total number of winners across all groups						-10,517
Net winners/losers in each area	-16.52%	-14.85%	-14.60%	-20.66%	-33.38%	
Share of the total population in the impact area	16.52%	14.85%	14.60%	20.66%	33.38%	
Assessment	X X	X X	X X	X X	X X	

4.3 Summary

The Webtag quintile analysis illustrates that some level of cost will fall on all LSOAs, and hence on all groups in society. Looking in more detail at the size of the impacts, the analysis of number of non-compliant trips into the CAZ suggests the direct impacts of the CAZ 1 will fall greatest on:

- the least deprived population quintile 5 of IMD
- highest ratio of persons with disabilities
- highest ratio of "non-white" people

Given all trips from those LSOAs located within the CAZ will be captured by the charging zone, the groups which experience greater effects mirrors those demographic groups which make up a greater proportion of the population living in Cardiff city centre. In addition, poorer households tend to own older, and more likely a non-compliant car.

These direct impacts for the CAZ 1 compare with the indirect impacts through change in travel times experienced with the CASAP scenario. These impacts have the potential to be progressive in nature if their journeys are directly impacted by the scheme and as a result suffer increased travel times, route changes or opt to change mode.

However, given uncertainty around these effects and the likely magnitude of the direct impacts under a CAZ 1, the CAZ 1 option is assessed as having the most negative impact in terms of household affordability.

Table 20: Summary of household affordability distributional impacts

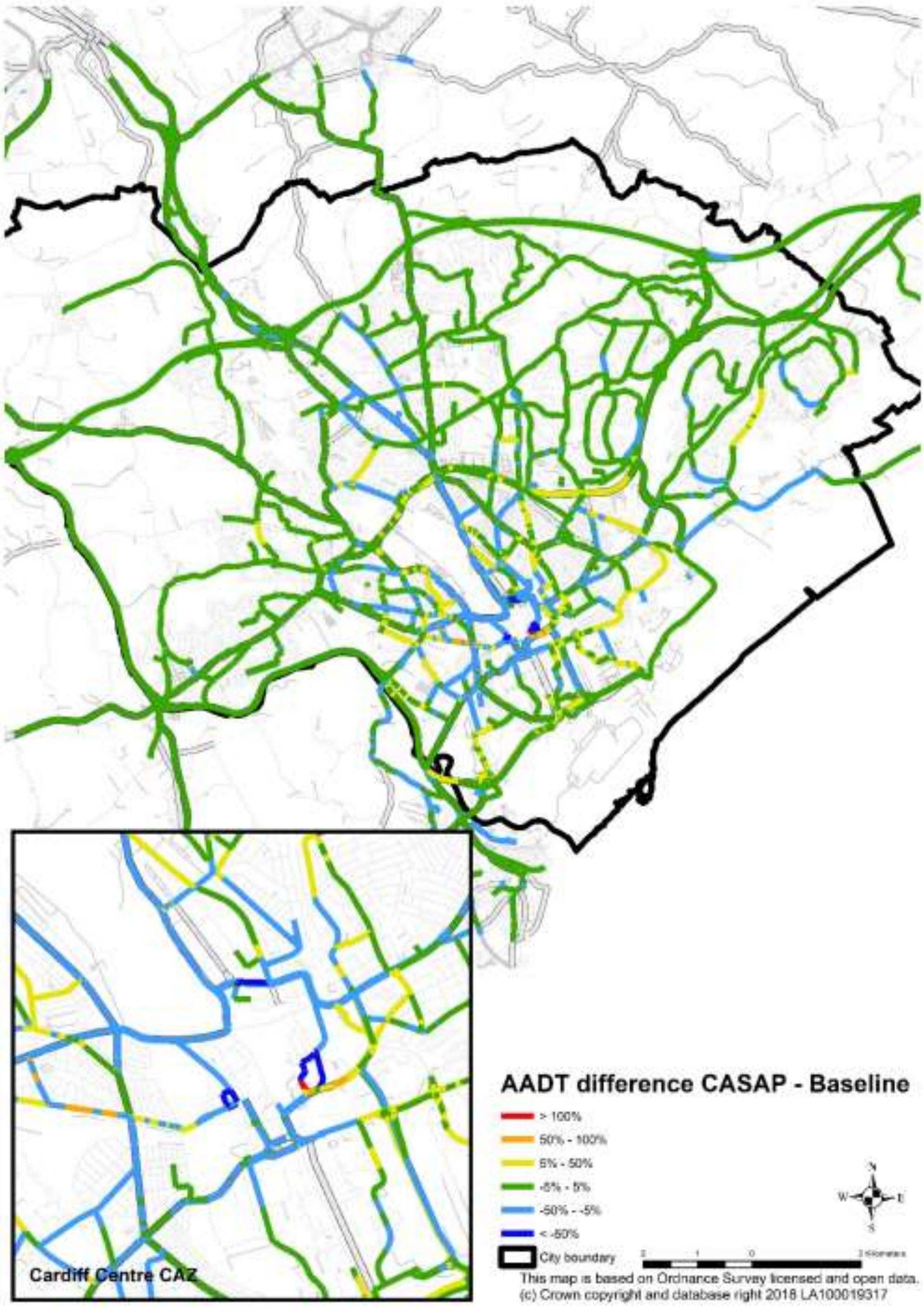
Scenario	Summary assessment
CAZ 1	×× • Webtag quintile analysis illustrates that some level of cost will fall on all LSOAs, and hence on all groups in society. • Looking in more detail, analysis suggests direct impacts will fall greatest on: least deprived population (quintile 5 of IMD), lowest proportion of under 16s (i.e. LSOAs with a rather old adult demographic) and lowest ratio of "non-white" people. • No distributional impact
CASAP	× • No direct impacts on households given cars not included in scope • Will be indirect impacts on households if their journeys suffer increased travel times, route changes or opt to change mode. •

5 Traffic impacts – noise/safety

5.1 Overview of changes in traffic flows

The overall change in AADT on each of the model roads is shown in Figure 13 for the CASAP scenario. As discussed in the following section, a significant change in traffic flow is expected to occur for only 0.44% of the road links for CAZ 1, but for 11.75% with the CASAP scenario.

Figure 13: Relative changes (in %) in traffic flows (AADT) from between the CASAP scheme and the Baseline for 2021



In the city centre there is an overall decrease in traffic flow with a CASAP scenario. Some sections will see an increase, such as Ninian Park Rd and Adam street. On the other hand, Churchill street or Bridge street will see a relevant decrease in traffic flow, due to the East side traffic management scheme included in CASAP. However, outside the city centre (delimited by the CAZ boundary), the traffic on average would not experience a significant increase or decrease.

5.2 Traffic Safety

The number of road traffic accidents recorded in each LSOA in 2017 was obtained from Road Safety Data STATS19, available from https://data.gov.uk. Using this dataset, we have been able to compute the national accident rates (for Wales) disaggregated by demographic groups as well as for the domain of study, based on the population at LSOA level from the Census 2011 data:

Table 21: Accident rates at national (Wales) and Cardiff city level disaggregated by quintiles for four demographic groups

Accident rates		Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Income	Wales	0.12%	0.13%	0.16%	0.16%	0.11%
	Cardiff	0.12%	0.13%	0.23%	0.13%	0.11%
Children	Wales	0.16%	0.16%	0.12%	0.12%	0.10%
	Cardiff	0.17%	0.11%	0.11%	0.16%	0.11%
Elderly	Wales	0.15%	0.12%	0.11%	0.14%	0.17%
	Cardiff	0.17%	0.12%	0.10%	0.11%	0.10%
Disability	Wales	0.12%	0.13%	0.12%	0.17%	0.15%
	Cardiff	0.12%	0.11%	0.13%	0.23%	0.11%

At a national level, accidents rates are highest for quintiles 3 and 4 for income, as well as the lowest proportion of children and highest proportion of elderly. The situation remains comparable for the region of Cardiff, but with higher accident rates for quintile 3 of deprivation or quintile 4 of disability. Figure 2 highlighted that over half of the population living within Cardiff scheme domain belong to the lowest three quintiles of the deprived population and are therefore more likely to be affected by road accidents.

Both scenarios are expected to impact the volume of traffic and speed. In addition, the predominant behavioural response to the CAZ 1 is anticipated to be for vehicles to either ‘upgrade’ or ‘pay the charge’, each of which has no resulting impact on traffic movements. However, where vehicle users opt to ‘avoid the zone’, ‘cancel journey’ or ‘mode shift’, this will impact on the volume and location of traffic travelling around the network, which will also impact on the volume of traffic on individual links and the speed of travel.

Implementing either a CASAP or a CAZ 1 scheme could therefore lead to changes in the traffic flow and speeds through rerouting of vehicles to different roads, potentially leading to an increase of accident rates and therefore safety implications for inhabitants. Any distributional impact will of course depend on the location and specific link where significant changes occur.

Two criteria have been applied to restrict the study to the main affected links:

1. Absolute change in AADT or traffic speed must be at least 10% (increase or decrease) of the baseline AADT link to be defined as a ‘significant’ change – given noise around the transport modelling, it is difficult to have confidence that smaller changes observed are truly an impact of

the scenarios or model noise. In addition, changes of 10% are considered as "neutral" in the WebTAG analysis.

2. Absolute AADT 2020 DM link should be higher than the first quintile in order to select significant roads – this removes links which show a large percentage change due to a low starting point: e.g. an increase in AADT from 1 to 2 will show an increase in 100%. Absolute traffic speed link should be at least 10 km/h on average to account only for roads with the highest probability of accident as well as noise.

Links meeting these criteria have been highlighted for the two scenarios.

WebTAG analysis indicates that a change in traffic flow or speed is considered as significant if it is at least 10%. Based on this assumption, Table 22 summarizes the number of links with significant increase or decrease in traffic volume or speed for both scenarios.

Table 22: Number of links with significant changes for both scenarios

Number of links	CAZ 1	CASAP
Significant decrease in traffic volume	32 [0.42%]	562 [7.35%]
Significant decrease in traffic speed	283 [3.70%]	384 [5.02%]
Significant increase in traffic volume	2 [0.02%]	337 [4.40%]
Significant increase in traffic speed	2620 [34.25%]	2309 [30.18%]

Implementing the CASAP scenario will lead to a much greater number of links experiencing a decrease in traffic flow in comparison to the CAZ 1 scenario, and especially in the city centre according to Figure 13. This is mostly due to the Westgate Street Scheme that is expected to remove traffic from this street. Some rerouting is however forecasted (e.g. Tudor Street). For both scenarios, a large number of traffic links (around a third of all links) is expected to experience an increase in traffic speed, due to less congestion and more fluid traffic in both scenarios.

According to Table 22 the links with significant changes in traffic speed is much higher than for traffic volume with a CAZ 1. Therefore, only changes in traffic speeds were taken into account to assess the impact on accident rates.

On the other hand, a CASAP would lead to a relevant number of links experiencing a change in traffic volume and traffic speed (overall 12% for traffic volume and 35% for traffic speed). Therefore, to account for changes in accidents at LSOA level, the links have been classified based on traffic volume and speed, as summarised in Table 23 below:

Table 23: Classification of changes in accident rates for the CASAP scenario

Relevant **decrease** in accident rates	Significant **decrease** in traffic speed AND significant **decrease** in traffic volume	
Slight **decrease** in accident rates	Significant **decrease** in traffic speed AND non-significant change in traffic volume	Significant **decrease** in traffic volume AND non-significant change in traffic speed

Relevant **increase** in accident rates	Significant **increase** in traffic speed AND significant **increase** in traffic volume	
Slight **increase** in accident rates	Significant **increase** in traffic speed AND non-significant change in traffic volume	Significant **increase** in traffic volume AND non-significant change in traffic speed

Based on the above criteria, links have been classified and LSOAs have been defined based on the number of links with an increase or decrease in accidents within its LSOA. Results are shown in Table 24 and Table 25. Overall the analysis indicates that links are predominately showing either an increase (for CAZ 1), slight increase (for CASAP) or no impact, with very few decreases. So for clarity of interpreting the data at LSOA level only the increase category is shown for the CAZ 1 (Table 24) as this is largely predominant and only the slight increase category is shown for the CASAP scenario (Table 25).

Table 24: Number of LSOAs with an increase in accidents disaggregated by quintiles of demographic population for the CAZ 1 scenario

Quintiles	1	2	3	4	5
Income	41	26	20	37	48
Under 16	44	28	33	30	37
Over 65	60	43	28	24	17
Disability	35	30	23	26	58
Women	41	21	26	31	53
Proportion of "non-white" people	0	0	7	46	119

Table 25: Number of LSOAs with a slight increase in accidents disaggregated by quintiles of demographic population for the CASAP scenario

Quintiles	1	2	3	4	5
Income	40	24	18	35	43
Under 16	39	26	34	25	36
Over 65	53	42	27	22	16
Disability	34	27	23	24	52
Women	36	19	26	30	49
Proportion of "non-white" people	0	0	7	42	111

Both scenarios would mostly be a disbenefit to the areas with the highest proportion of people with disability, "women" and "non-white". In addition, the areas with the lowest population of children and the elderly would also suffer from the implementation of such scenarios. However, the trend is clear for the income metric as it seems to primarily disbenefit to the lowest and highest incomes.

From the results presented above, no clear differences can be made between both scenarios, which overall would lead to an increase in accident rates mostly due to a general increase in traffic speeds. However, a number of things should be noted:

- The number of links showing a speed increase is potentially over estimated by the traffic model and the way in which the daily speeds are averaged from the different time periods;
- The CASAP option overall shows a decrease in speeds and flows in the central area which is a result of the city centre measures and the aim to improve the pedestrian and cycling environment here.

- The analysis does not take account of measures designed to improve safety directly such as improved crossing, cycling lanes, etc that are a feature of the city centre schemes in the CASAP scenario designed to reduce accidents and encourage these modes.

5.3 Noise

As previously discussed, both schemes could impact traffic volume and traffic speed, both influencing the noise levels for habitants near roads. Tag Unit A3 defines a significant change in noise levels to be at least 3dB. Considered independently, this threshold is obtained when there is at least a change in traffic volume of 50% (for L_{Aeq}) and in some cases a speed change of at least 10 km/h (for L_{AE}) (Annecke et al., 2008. Table 26 and Table 27 reports the number of links with a change in traffic volume of at least 50% for both scenarios:

Table 26: Number of links corresponding to a significant change in traffic volume for the two scenarios.

Change in traffic volume [corresponding change in noise levels L_{AEQ}]	<-75 % [at least 6.0 dB]	-75% - -50% [3.0 dB – 6.0dB]	50%-75% [3.0 dB -6.0 dB]	>75% [at least 6.0dB]
CAZ 1	0 [0.00%]	0 [0.00%]	0 [0.00%]	0 [0.00%]
CASAP	16 [0.21%]	5 [0.07%]	11 [0.14%]	12 [0.16%]

Table 27: Number of links corresponding to a significant change in traffic speed for the two scenarios

Change in traffic volume [corresponding change in noise levels L_{AEQ}]	<-10 km/h	>10 km/h
CAZ 1	27 [0.35%]	88 [1.15%]
CASAP	71 [0.93%]	77 [1.01%]

The number of road links that could be impacted by a both schemes in terms of noise levels is not significant: It corresponds however to a very small fraction of the total number of links (less than 1.2% at the highest) and so the overall impact on noise levels remains limited for both schemes.

5.4 Summary

Both scenarios could lead to an increase in accident rates in the city of Cardiff due to increases in traffic speeds away from the city centre, but this is balanced by a reduction due to less traffic in the centre. The benefits in the central area will be enhanced by measures designed to improve safety for pedestrians and cyclists that are not specifically accounted for in this assessment. It would potentially impact mostly the areas with the highest proportion of people with disability, which are more vulnerable to changes in accident rates. In addition, the increase in accident rates would occur in zones with low proportion of children or the elderly. However, overall, the distributional impact in relation to demographic groups is potentially limited.

Overall the CAZ 1 or CASAP scenarios would have a rather neutral impact on noise on the population living in Cardiff, but an overall negative impact on accident rates, widespread within the city for both scenarios.

Table 28: Summary assessment for traffic impacts

Scenario	Summary assessment	
CAZ 1	X	• Implementing a charging scheme would lead to an overall increase in traffic speed throughout the city, and therefore a worsening in traffic safety.
CASAP	-	• The CASAP measures may result in speed increases in some area but this is balanced by a reduction in traffic flows in the central, complemented by spefic measures to improve safety.

Note:
- no impact
X negative impact
✓ positive impact

The distributional impact in relation to demographic groups is therefore only seen for accidents but is potentially limited. In general the greatest benefits are seen for low income households and those with children under 16.

6 Traffic impacts – Accessibility

6.1 Methodology

There is the potential for accessibility impacts where the policy option:

1. Changes public transport provision, including routing, frequencies, waiting facilities (bus stops / rail stations) and rolling stock, or any indirect impacts on accessibility to services (e.g. demolition & re-location of a school).
2. Impacts on provision of services/amenities through indirect impact on demand
3. Places physical barriers which limits travel across the network.

However, any accessibility impacts are likely to be limited in this case given the nature of the refined shortlist of options under consideration for Cardiff:

- A charging CAZ will not put up physical barriers to travel across the network. The options only place additional costs on vehicle users. Hence any resulting limitations around travel are inherently associated with affordability, which is considered separately above
- The charging CAZ options do not plan to remove or change public transport services: The CAZ proposes no change to service routes, frequencies, or locations of access. The only potential impact will be to upgrade to buses. Hence there will be no impact, assuming upgraded vehicles make the same or better provisions for disabled users
- It is unlikely that there will be any impact on provision of services through changes in demand. The dominant behavioural response to the CAZ will be to upgrade vehicles or to pay the charge. Only a very small fraction of users are anticipated to ‘cancel journeys’ hence there is unlikely to be a significant impact on demand for services.

The only additional and significant accessibility impact could be through general changes in congestion, which will impact on the travel time to amenities. This is the focus of the qualitative analysis undertaken here.

6.2 Qualitative analysis

Modelled travel times data for both options (CAZ 1 and CASAP) was provided by Mott MacDonald as an output of their transport model. The data shows the average travel time in minutes from each origin transport model zone to all other zones within the transport model.

In order to best represent the changes in travel times for both scenarios, a model zone within the CAZ area has been selected: zone 595 (see Figure 14). After discussion with Mott MacDonald, this zone was chosen as representative of the traffic flow changes for both scenarios. It also includes the St. David's carpark, a key amenity within the CAZ area. However, as CASAP included traffic schemes at different places, the results could differ with another zone.

For this study, the travel times for commuting cars during the AM period were considered as representative of the traffic accessibility and it would show the largest changes in travel time in relation to household accessibility. Absolute (in mins) and relative (in %) changes in travel times from a zone within the DA domain and the zone in the centre between both scenarios were calculated.

The results in Table 29 and Table 30 illustrate the effects on travel time change for both scenarios to the city centre.

Table 29: Absolute change in travel times (in minutes) defined by percentage of transport model zones of origin

Range of impacts (minutes)	CASAP	CAZ 1
<-10	0.00%	0.00%
-10 to -5	0.00%	0.00%
-5 to -3	0.00%	0.00%
-3 to 0	1.52%	96.19%
0 to 3	42.87%	3.81%
3 to 5	31.66%	0.00%
5 to 10	22.85%	0.00%
>10	1.09%	0.00%

Table 30: Relative change in travel times (in %) defined by percentage of transport model zones of origin

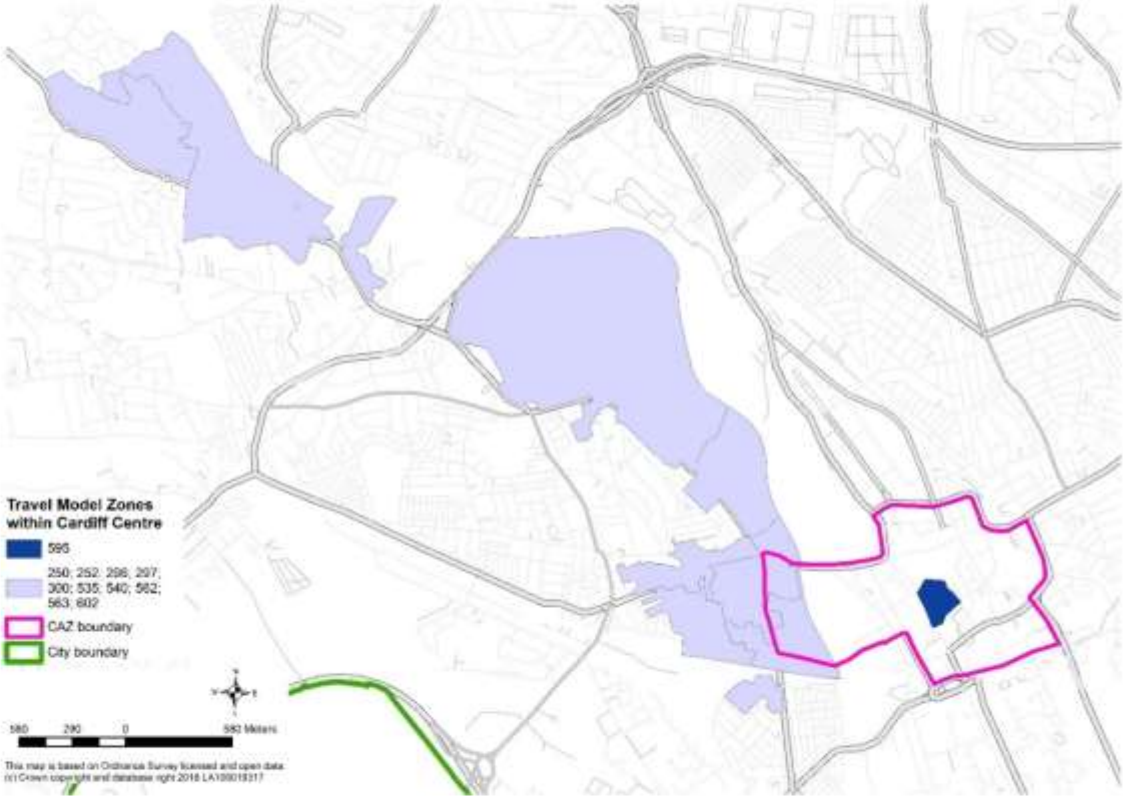
Range of impacts (%)	CASAP	CAZ 1
<-16%	0.00%	0.00%
-16% to -6%	0.11%	0.00%
-6% to -2%	0.54%	6.20%
--2% to 2%	2.18%	93.80%
2% to 6%	22.20%	0.00%
6% to 16%	47.88%	0.00%
>16%	27.09%	0.00%

With the implementation of a CAZ 1, all changes in travel times are within 3 minutes (either positive or negative), and therefore not likely to be perceived by the population and the overall impact is considered to be "neutral".

On the other hand, a CASAP scenario would lead to around 30% of "zones" which on average will experience an increase in travel times by 16%, with 1% being over 10 minutes. Therefore, this scenario is considered to have an adverse impact in terms of travel time on the population.

Figure 14 shows that the regions where the travel times will increase by more than 10 minutes with a CASAP. In those zones, the average time in the 2021 Baseline is 15 minutes. Therefore, an increase by more than 10 minutes is considered as significant. They are located in the north west of the city centre, alongside Cardiff Road (A4119). From Figure 3 and Figure 4, the populations in these areas is a high income population with a low proportion of children and would be the most impacted by the implementation of the CASAP scenario.

Figure 14: traffic model zones (in light blue) with an increase of 10 minutes in travel times to the city centre (in dark blue) for a CASAP scenario



6.3 Summary

Based on the previous analysis, the assessment of the traffic accessibility for the CAZ 1 and CASAP scenario is summarised as follows:

Table 31: Summary of traffic accessibility distributional impacts

Scenario	Summary assessment
CAZ 1	- • No significant impacts could be identified
CASAP	X • The area in the north west of the city centre could experience an increase in travel times by more than 10 minutes. In those areas live the least deprived population with a low ratio of children

However, it should be noted that the impact on travel time of the CASAP option is uncertain as the underlying transport modelling does not account for the demand response for the city centre measures, so these delays are a likely to be a maximum. Full demand modelling would be likely to reduce these delays. In addition, further mitigation measures that are being considered have not been included in the model and these would serve to further reduce these delays.

7 Conclusions

Our analysis has explored how the benefits and costs are distributed for the two options under consideration in Cardiff: the CASAP scheme and the CAZ scheme. The distribution of impacts have been looked at under three categories: air quality, household affordability and traffic impacts. The key findings against each of these categories are set out below:

Air Quality

- CAZ 1 and CASAP overall have an air quality benefit for most LSOAs with the greatest benefit within the charging zone and the city centre and some small dis-benefits outside. These benefits are not distributed evenly and there is a clear trend with both income and households with children under 16. Low income households are seeing the greatest benefit and higher income households the least benefit. In terms of children those households with the least children are seeing the greatest benefit and those with the most the least benefit. These both correspond with the characteristics of households within the charging zone. A CASAP scenario leads to an overall greater benefit for the population in the Cardiff than a CAZ 1.
- When looking at sensitivity receptors, for the charging scheme and CASAP, all categories of receptors on average see an air quality improvement, with the greatest improvement being from the CASAP scenario and within the charging zone and the city centre. Those that benefit most are educational residences and communal residences.

Household affordability

- The CASAP scenario that includes traffic management schemes may generate a small direct impact on households in relation to journeys that could be affected by the scheme either by diversion or changing mode. There may also be a small indirect impact through affects to business, primarily relating to deliveries. However, no specific distributional impact between different social groups is expected.
- The charging scheme will have a direct impact on households with non-compliant vehicles. The analysis of trips to the CAZ area with non-compliant cars indicate that the least deprived population would be the most impacted as they do the most trips into the charging zone. However, in relative terms as low income population tends to own more non-compliant vehicles, they would also directly suffer from the charging scheme.

Traffic impacts

- Both of these schemes are generating impacts through diversion of vehicles as either a result of the traffic management schemes in CASAP or avoiding the charging zone. Therefore, both have the potential to have noise or accident impacts related to changes in traffic activity.
- In both cases, a traffic decrease is expected in the city centre and increase elsewhere, due to rerouting.
- Both scenarios would have an impact on traffic, mostly an increase in traffic speed. This will potentially lead in both cases to an increase in accident rates in Cardiff. However, inporvements are expected in the central area for the CASAP option because of reduced traffic levsls and specific safety measures for pedestrians and cyclist.
- In both cases, the analysis traffic data at LSOA levels indicate that the areas with the lowest proportion of children and the elderly could experience an increase in accident rates. However,

the areas with the highest proportion of people with disabilities, vulnerable to traffic safety, may also suffer from an increase in accident rates in both scenarios.

- The accident analysis does not show a clear distributional trend with respect to income with lower and higher income households potentially seeing greater accident disbenefits from both schemes.
- In terms of noise neither of the schemes would be expected to have a significant impact based on the WebTAG guidance.

Traffic accessibility

- A charging scheme would not lead to significant changes in travel times.
- In contrast with the CASAP scheme the North west region outside of the city centre could see travel times increase by more than 10 minutes (for a 15 minutes average travel time) when going to the city centre. In those areas, the analysis at LSOA level indicates a population with higher income and with a low proportion of children will be most affected. However, this impact is uncertain due to the limitation of the model in terms of demand response to the city centre schemes and the impacts of longer term transport measures which are not included in the model.

Both schemes solve the compliance issue on Castle Street and generate broad air quality benefits across the city, more pronounced with the CASAP scenario than CAZ 1. In addition, a charging scheme will lead to much greater costs to households due to the direct and indirect impact of the charges. If a the higher income population seems to disbenefit the most from the introduction of the charging scheme, this is balanced by a greater proportion of non-compliant cars own by the lower income population. The traffic management schemes included in the CASAP scenario will lead to an overall relevant decrease in traffic flows in the city centre, such as Castle Street, Churchill Way or Bridge street, balanced by an increase on the roads in the vicinity of the scheme due to rerouting, such as Ninian Park Road or Adam Street; In both cases, because of an overall s increase in traffic speeds in the wider city, both scenarios could potentially increase in accident rates.

Table 32: Summary assessment of distributional analysis

Scenario	Air quality	Affordability for households	Traffic (noise and accidents)	Traffic (Accessibility)
CAZ 1	✓	✗✗	✗	-
CASAP	✓✓	✗	-	✗

Appendices

Appendix 1: Mapped variables

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Appendix 1 – Mapped variables

Figure A. 1.1: Map of IMD quintiles for DA domain – where quintiles reference modelling domain.

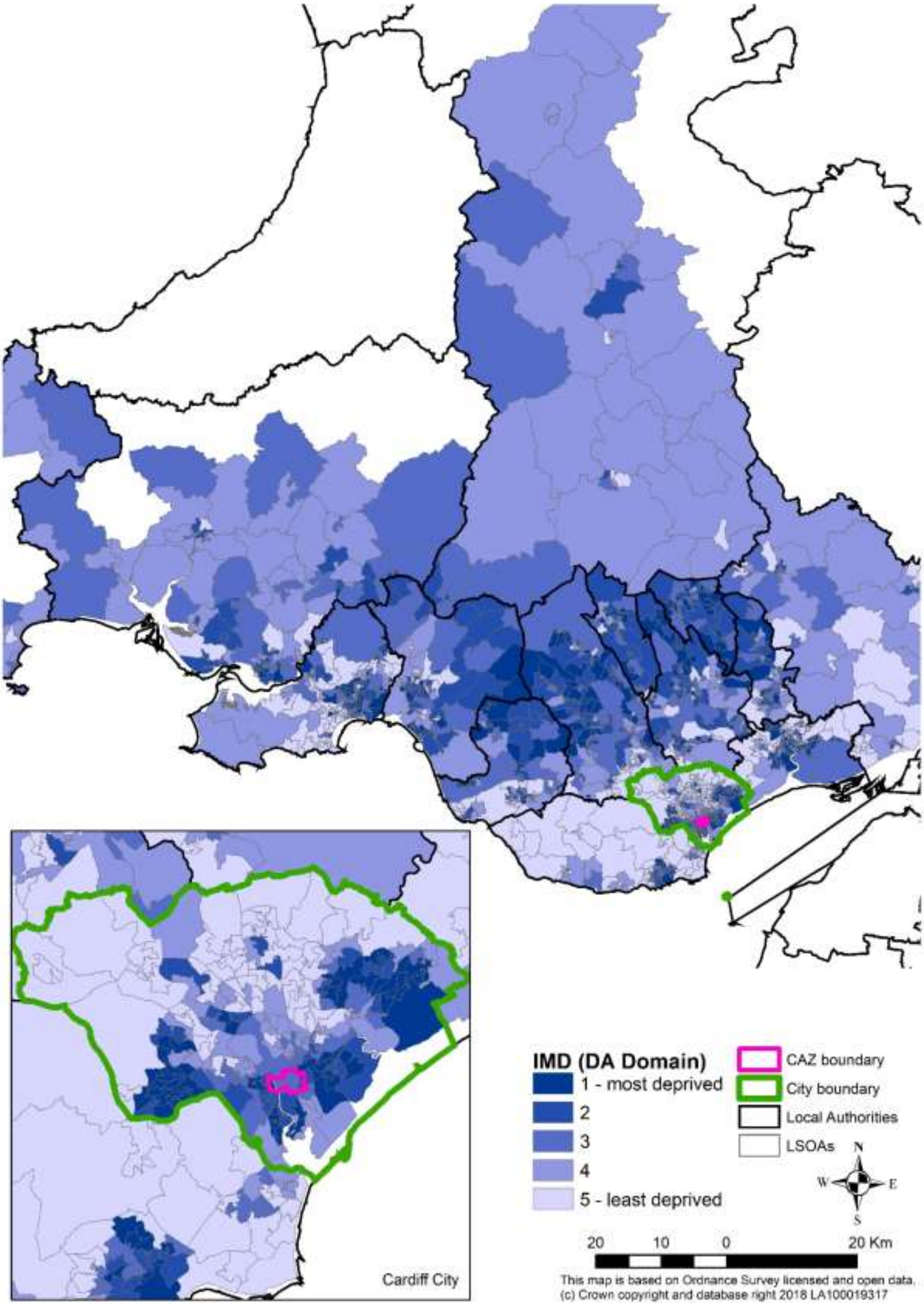

Figure A.1.2: Map of IMD quintiles for DA domain – where quintiles reference Wales.

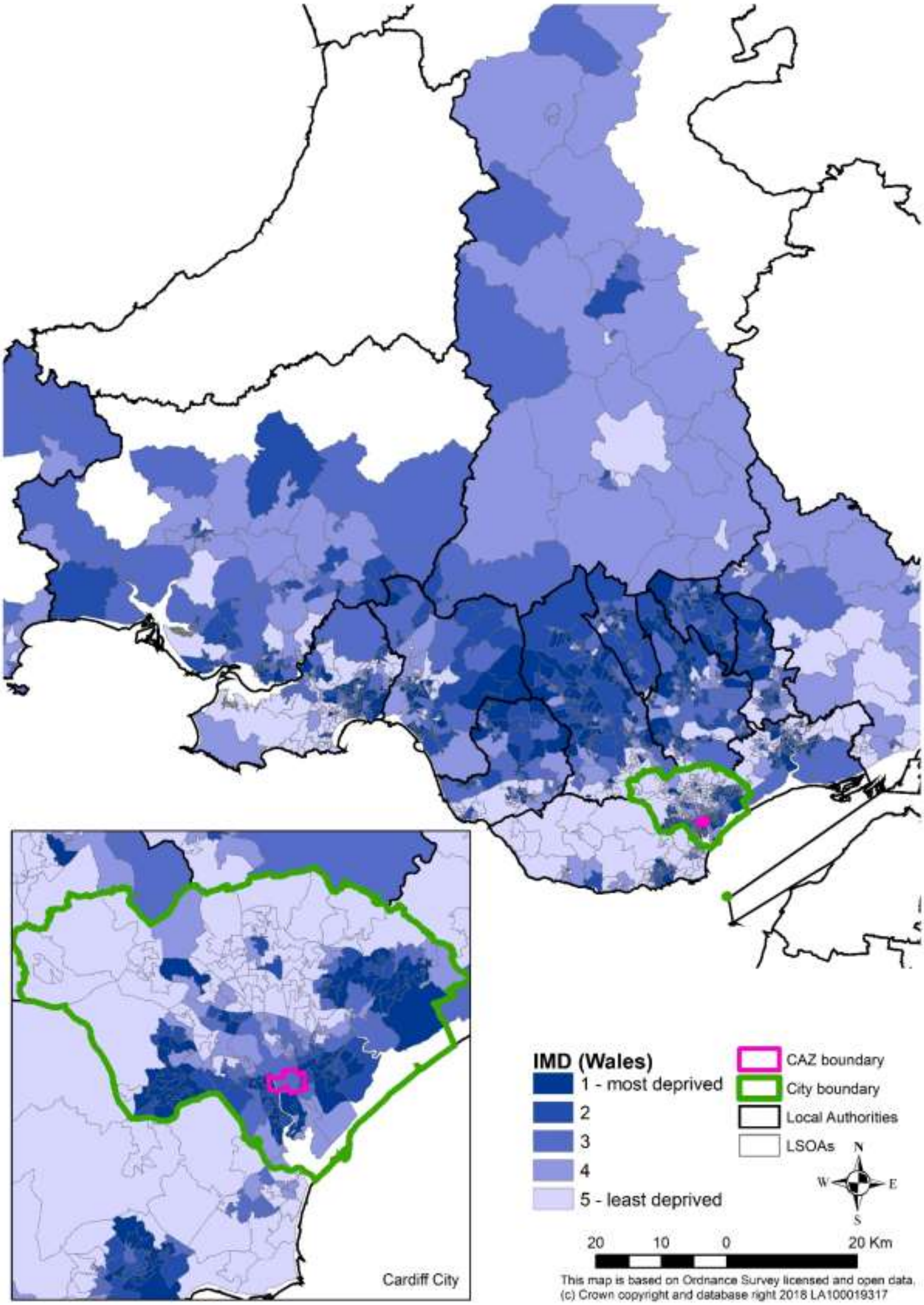

Figure A.1.3: Map of % population under 16 quintiles for DA domain - where quintiles reference whole England and Wales.

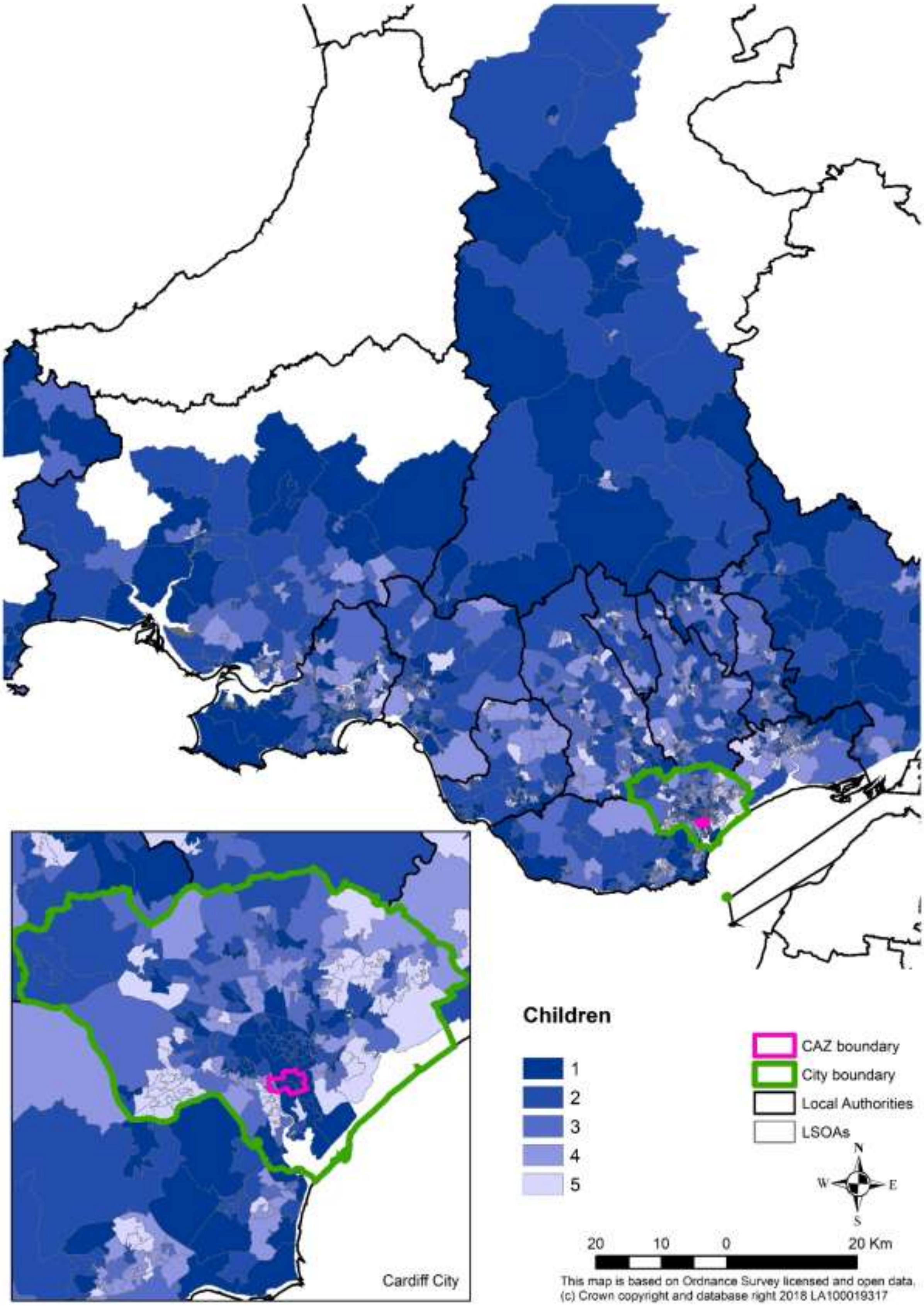

Figure A. 1.4: Map of % population over 65 quintiles for DA model domain - where quintiles reference whole England and Wales.

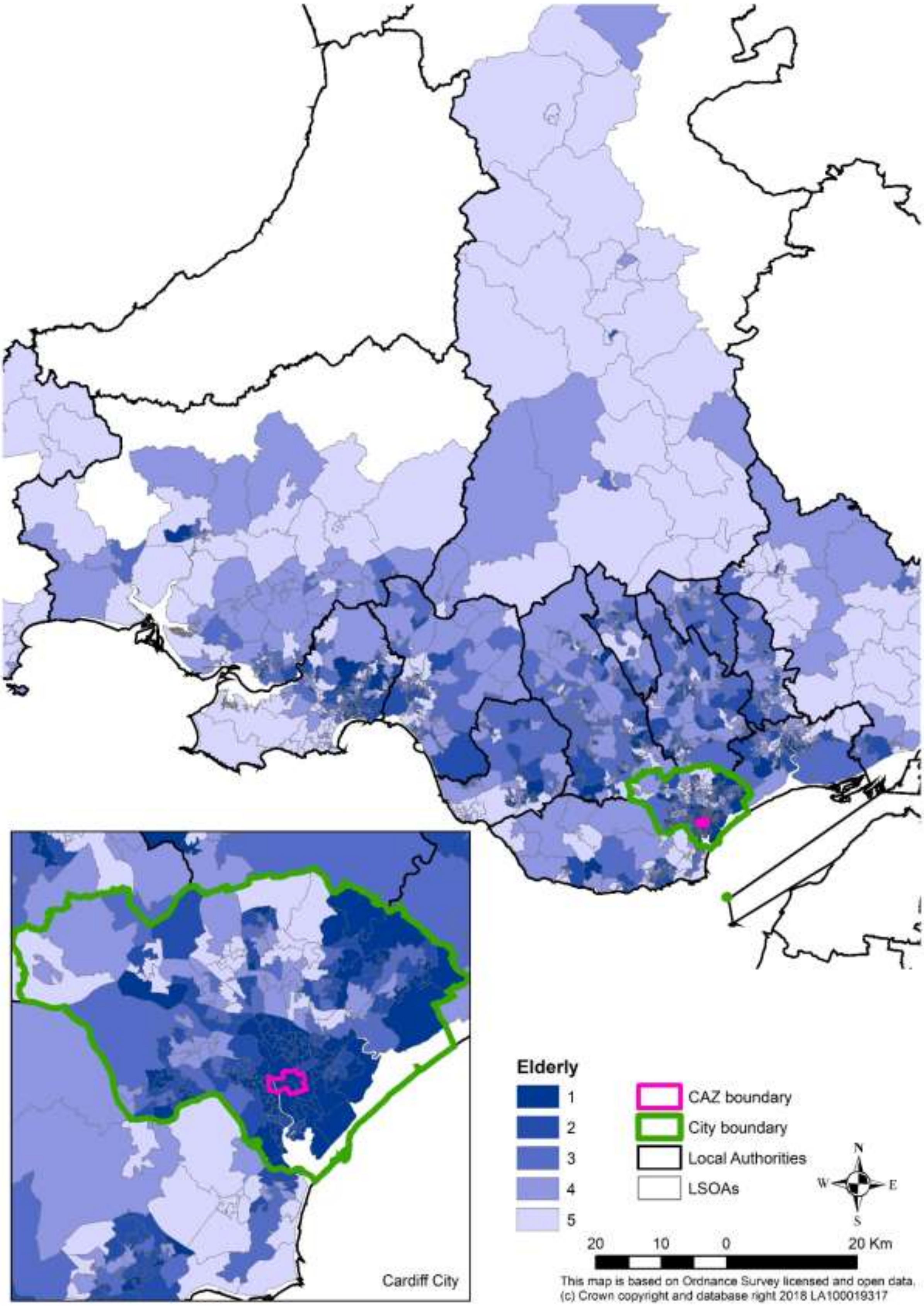

Figure A.1.5: Map of disability IMD data quintiles for DA model domain - where quintiles reference whole Wales.

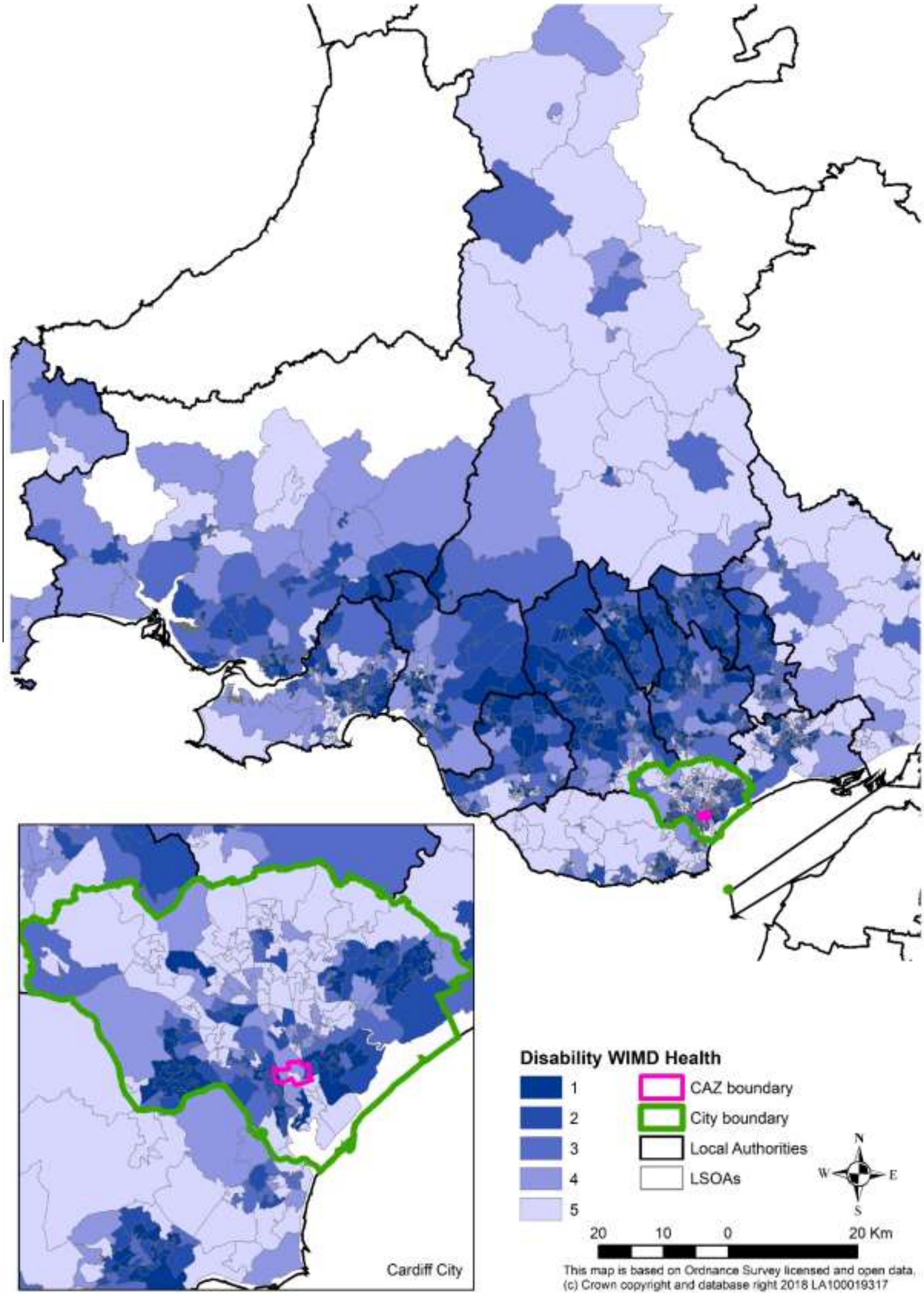

Figure A.1.6: Map of % women quintiles for DA model domain - where quintiles reference whole England and Wales.

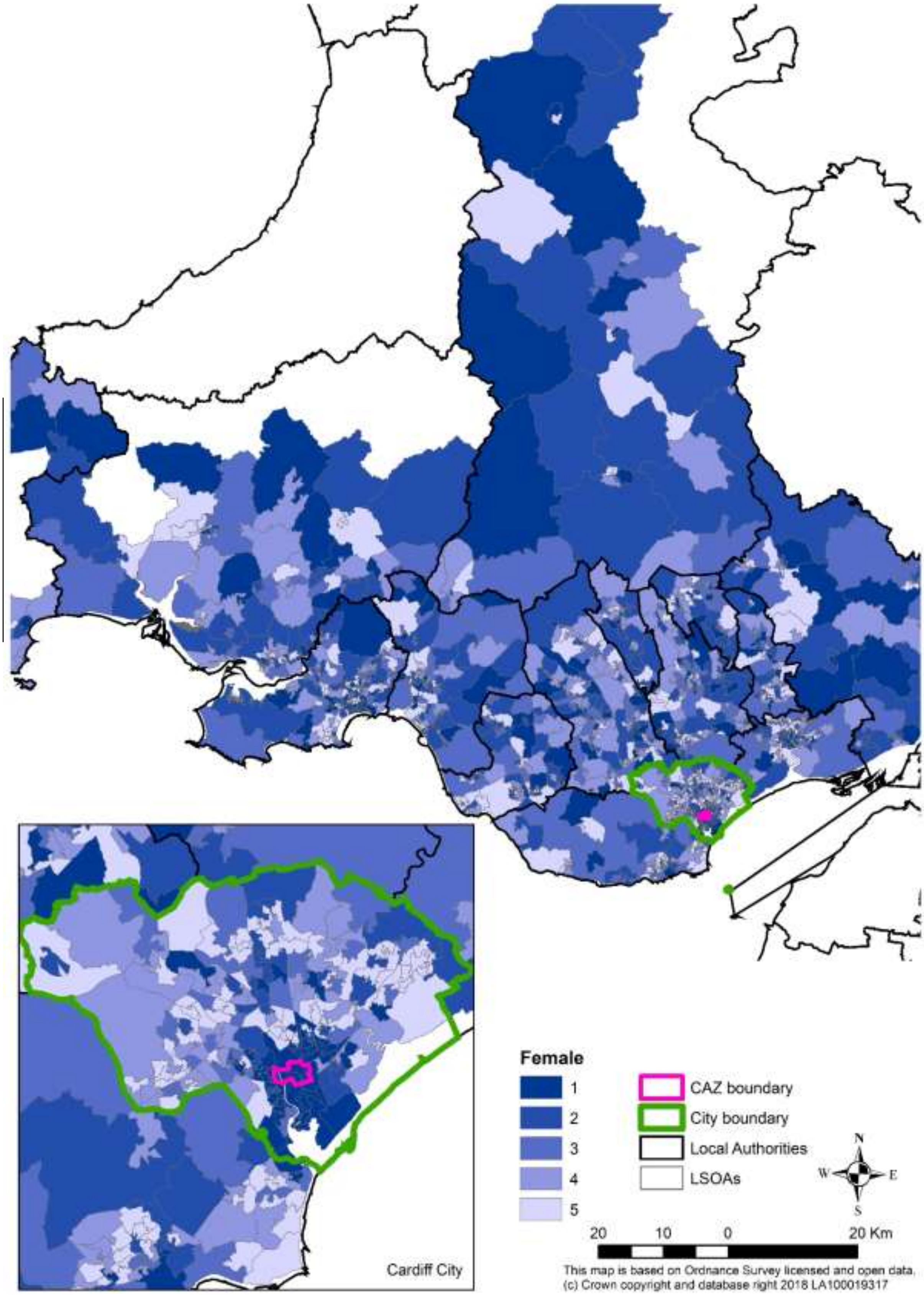

Figure A. 1.7: Map of Ethnicity quintiles for DA model domain - where quintiles reference whole England and Wales.

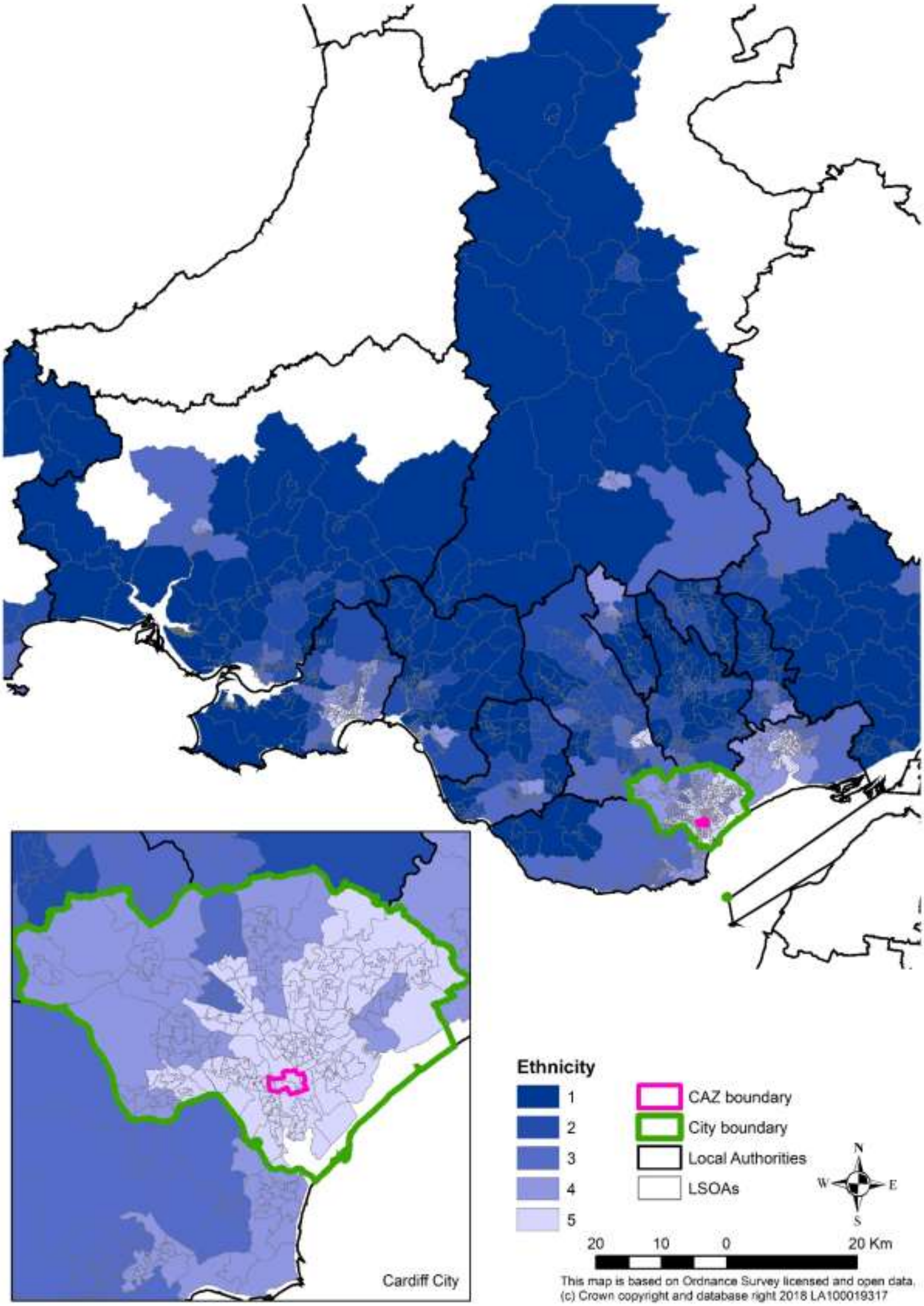

Figure A.1.8: Map of vehicle ownership pattern - % all non-compliant LGVs in LSOA (based on JAQU data).

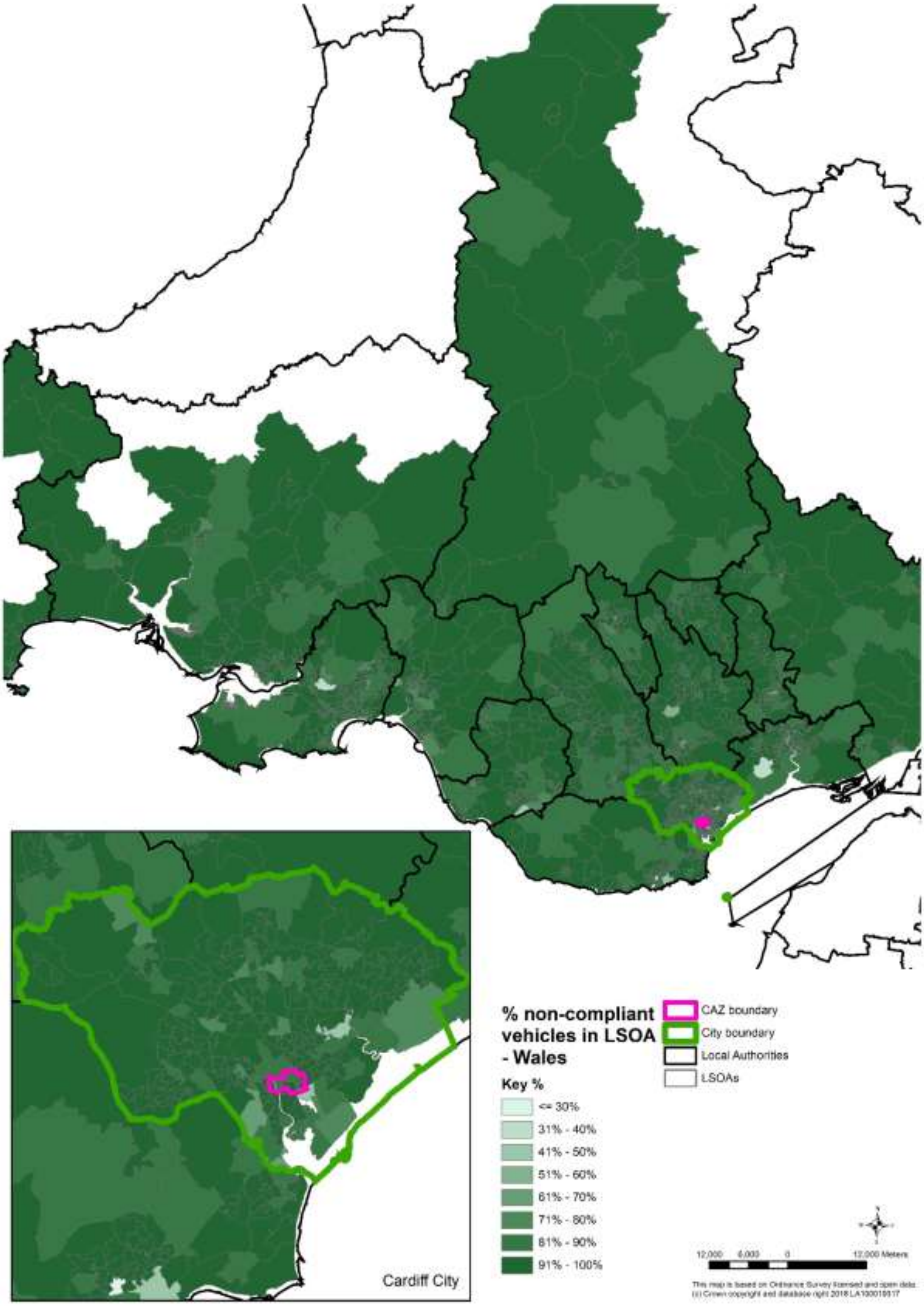

Figure A.1.9: Map of vehicle ownership pattern - % all non-compliant LGVs in LSOA (based on JAQU data) – zoom to Cardiff Centre.

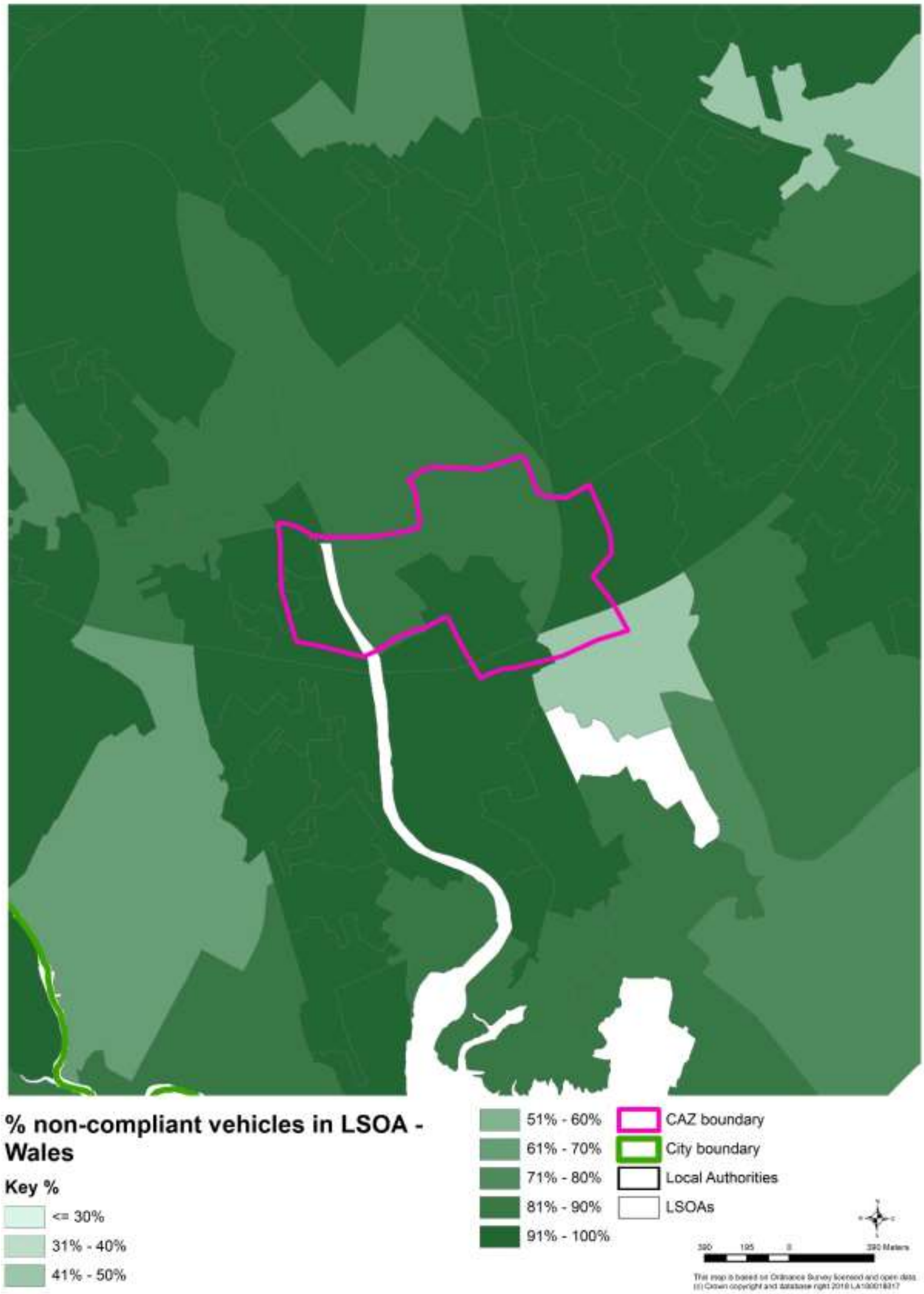

Figure A.1.10: Map of LGVs owned quintiles - where quintiles reference whole England and Wales (based on JAQU data).

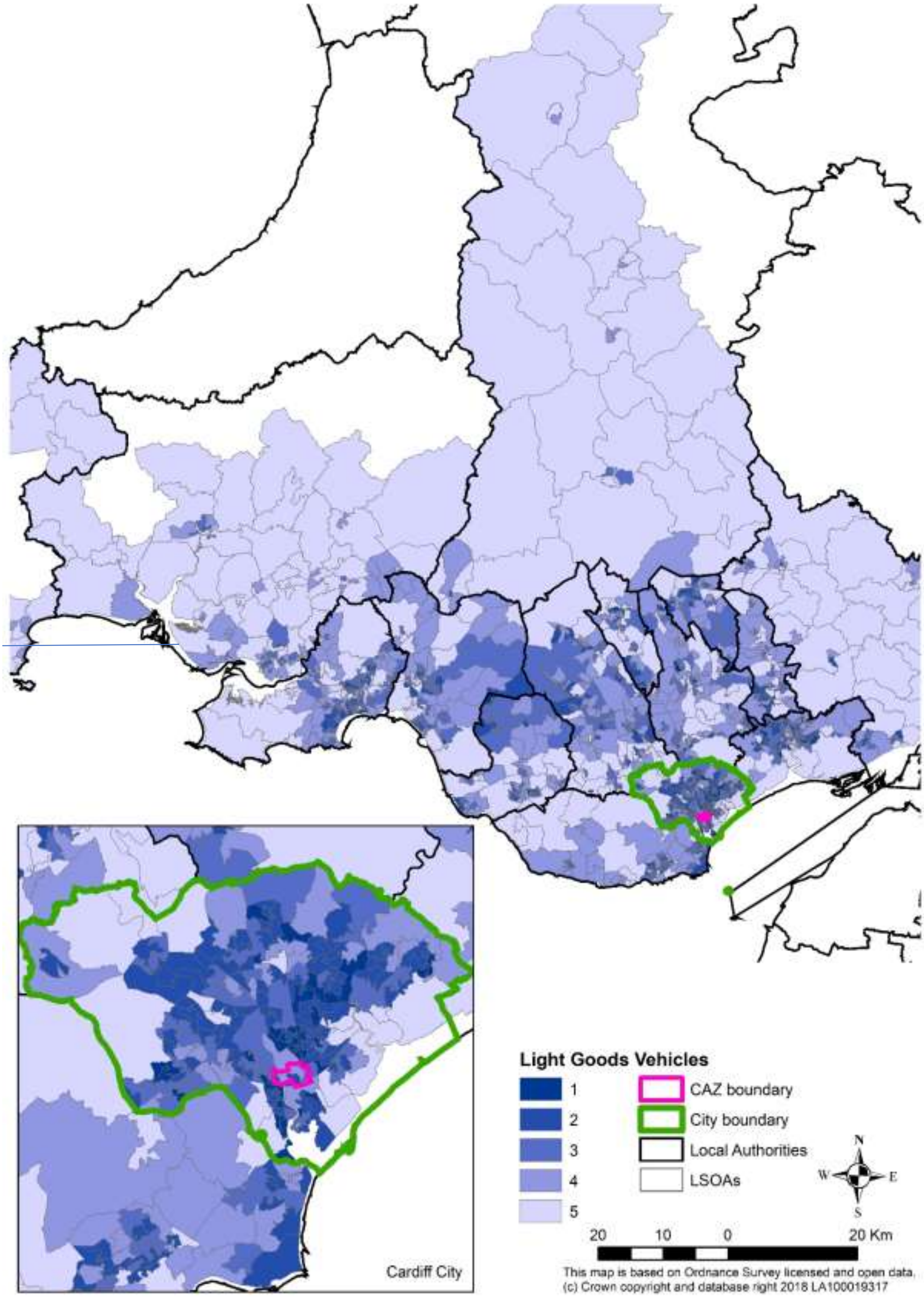

Figure A.1.11: Map of all business quintiles - where quintiles reference whole England and Wales.

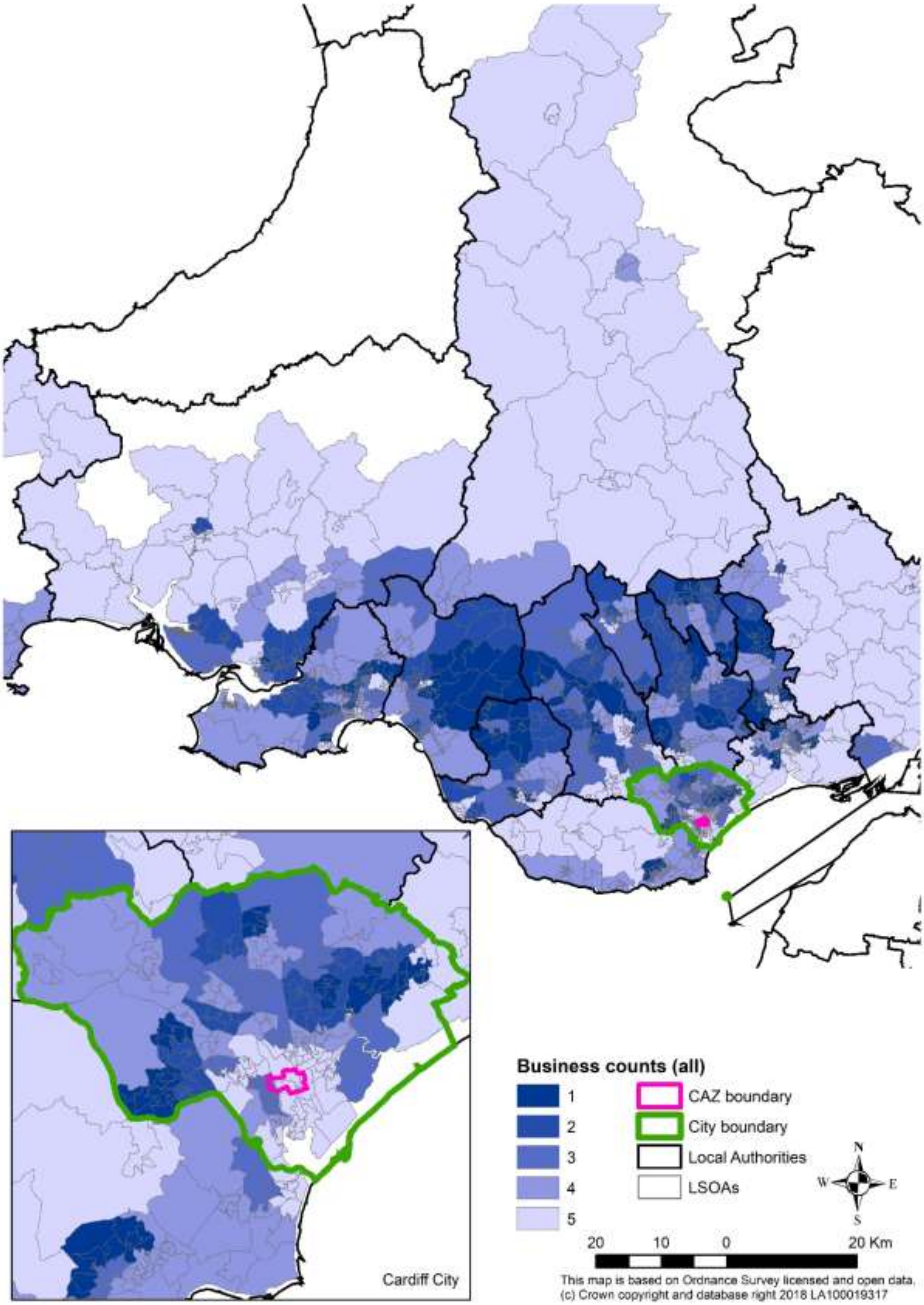

Figure A.1.12: Map of vehicle ownership pattern - % all non-compliant cars in LSOA (based on JAQU data).

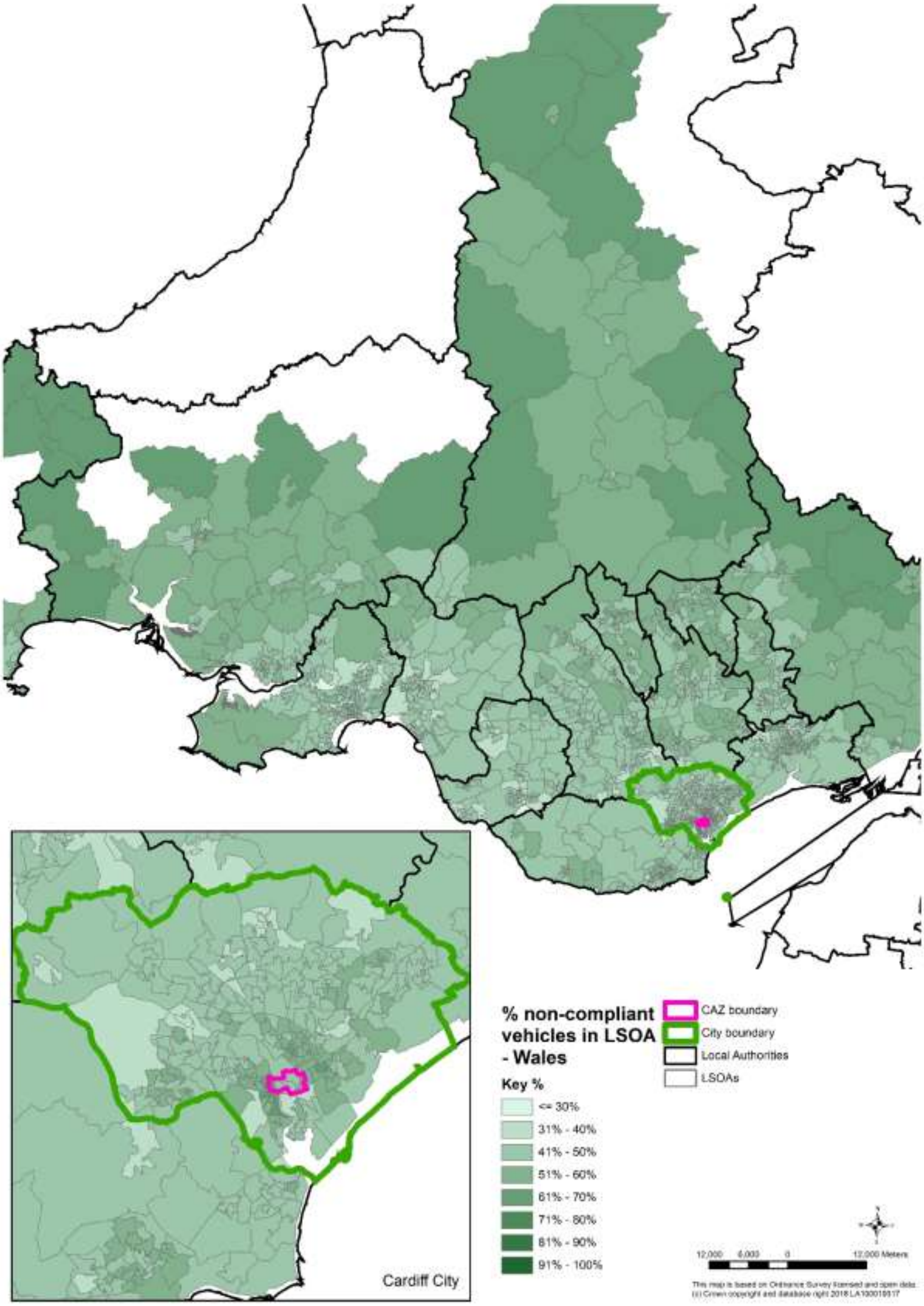

Figure A.1.13: Map of vehicle ownership pattern - % all non-compliant cars in LSOA (based on JAQU data) – zoom to Cardiff Centre.

Figure A.1.14: Map of all Small and Medium (SME) businesses quintiles - where quintiles reference whole England and Wales.

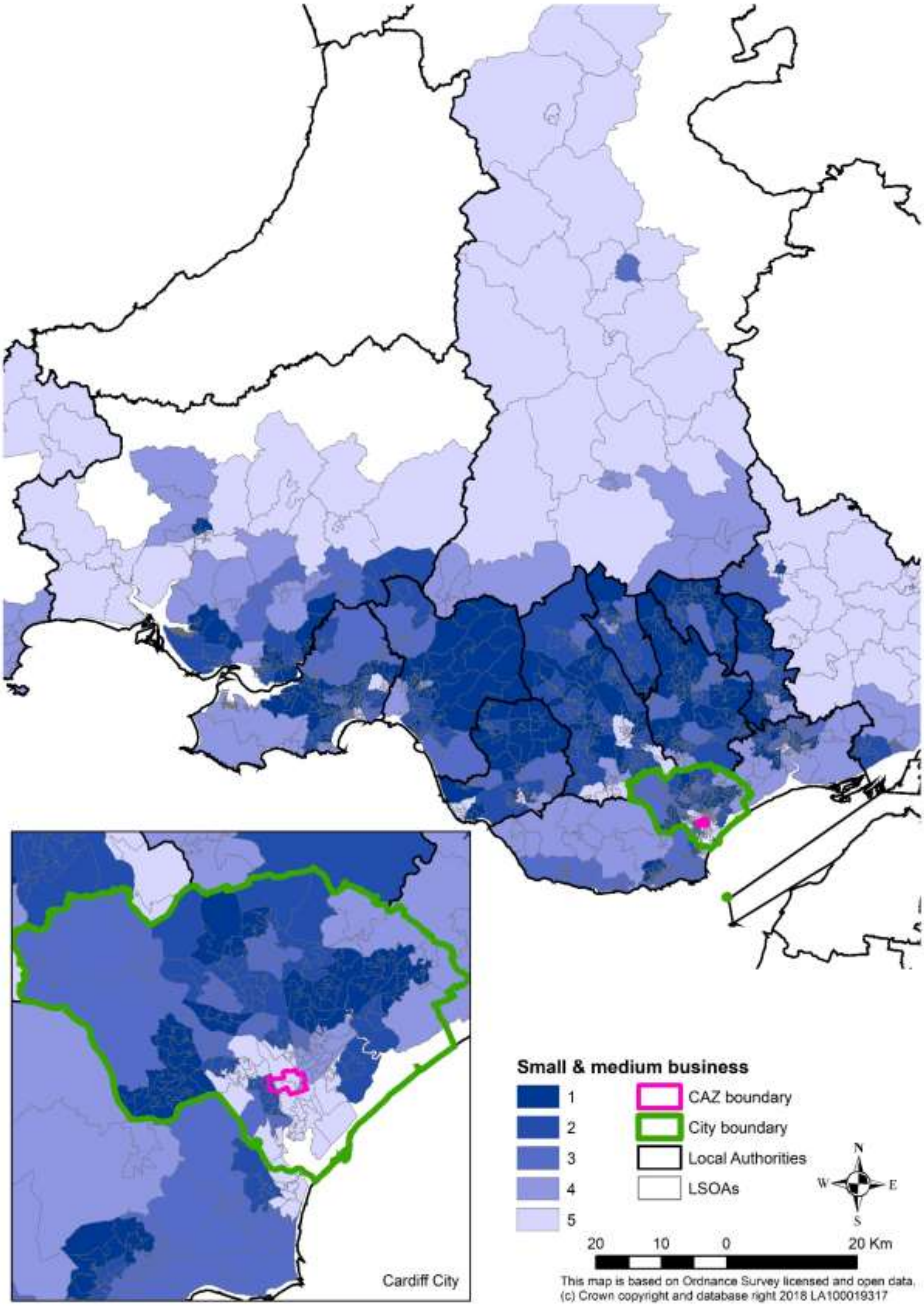

Figure A.1.15: Map of IMD quintiles for DA domain – where quintiles reference modelling domain – zoom in to the city centre

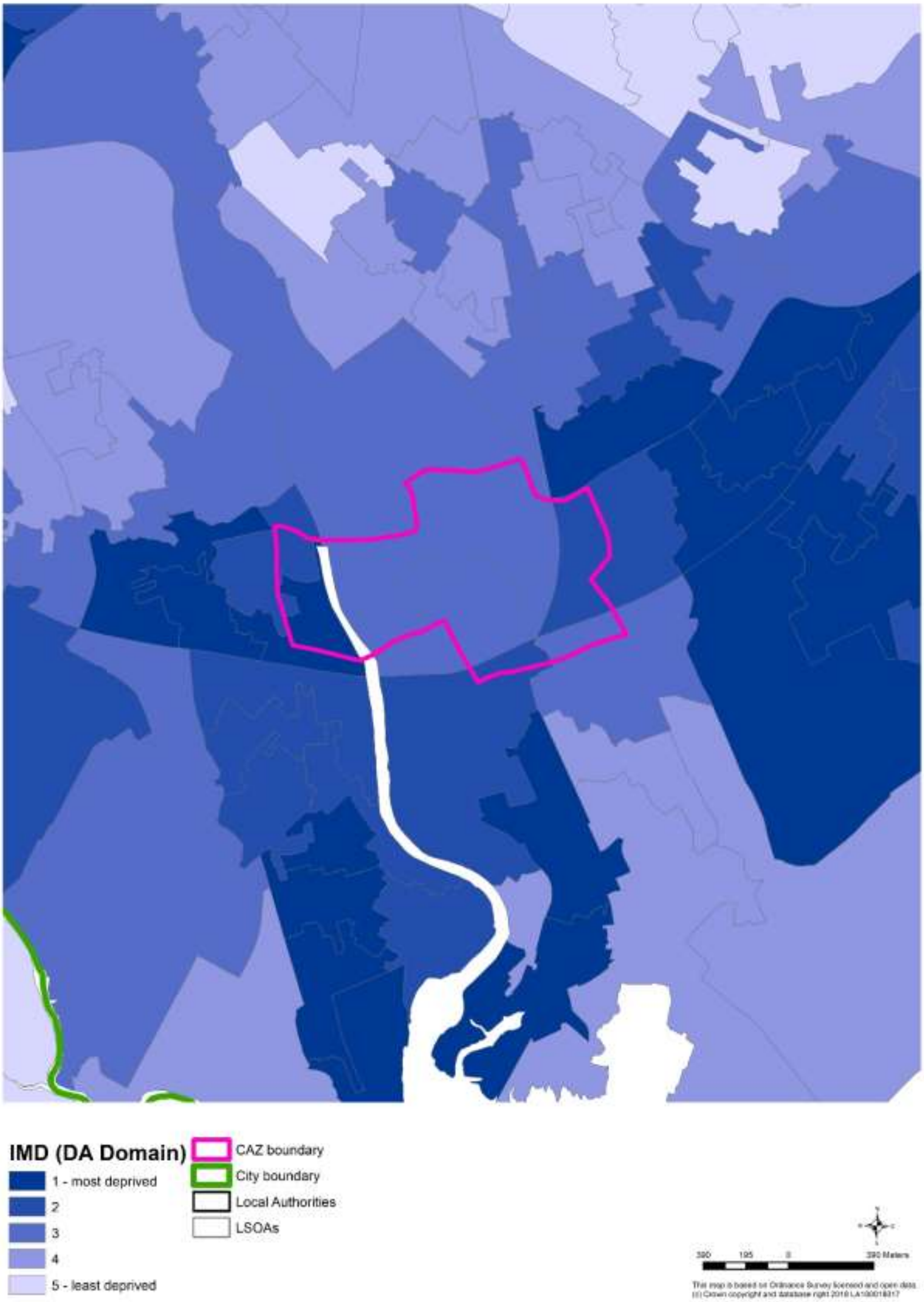

Figure A.1.16: Map of Under 16 quintiles for DA domain – where quintiles reference modelling domain – zoom in to the city centre

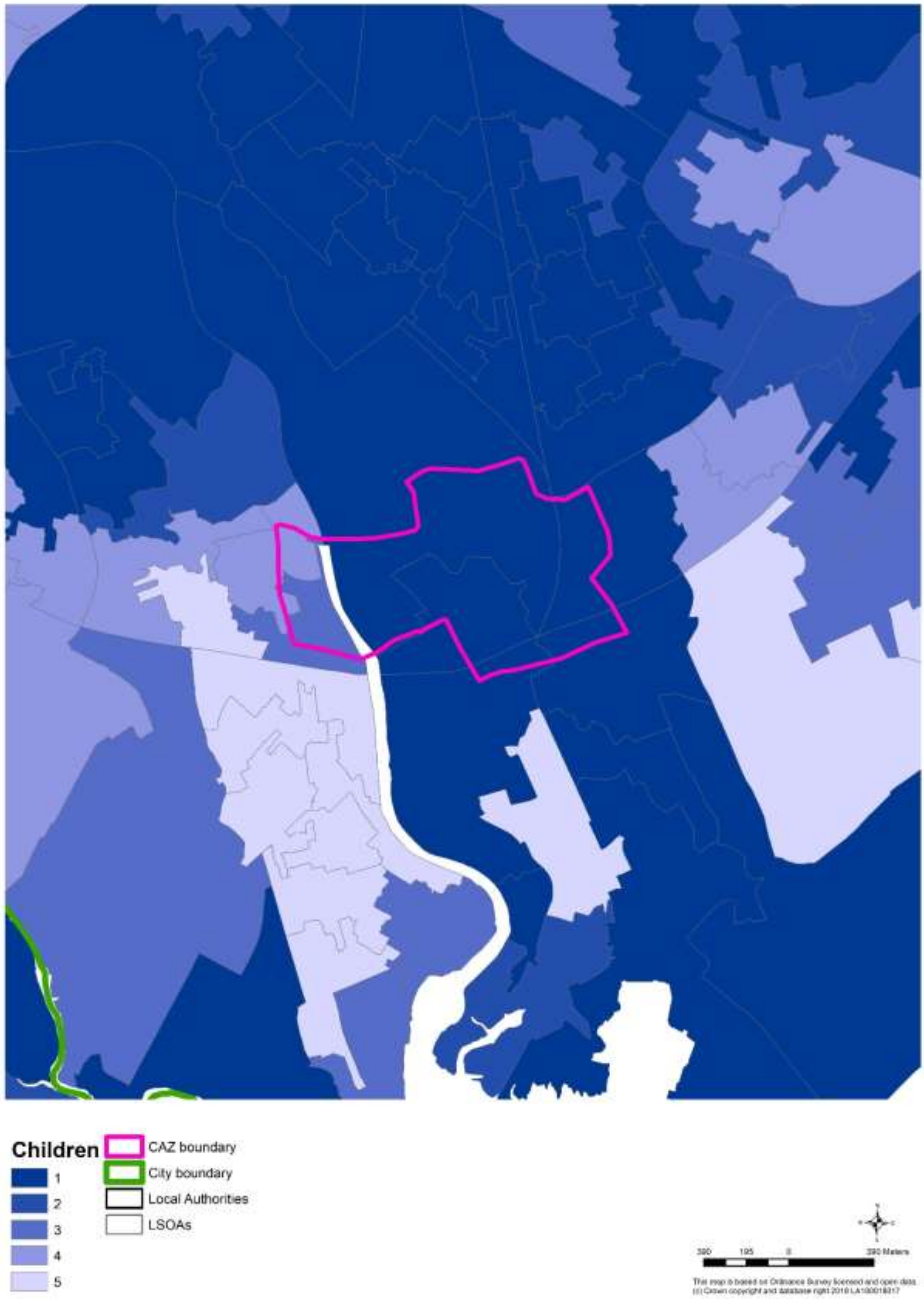

Figure A.1.16: Sensitive receptors in the city centre.