MOTT MACDONALD

# Technical Note

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| **Project:** | Cardiff Clean Air Feasibility Study | | |
| **Our reference:** | 367590 | **Your reference:** | - |
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| **Subject:** | 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. Transport modelling has been undertaken in the South East Wales Transport Model (SEWTM) using methods that are appropriate for a high-level feasibility study, with outputs being provided to Cardiff Council's air quality consultants (Ricardo). The overarching purpose of the transport modelling work for this study is to assist in forecasting air quality conditions with and without specific interventions on the transport network.

## 1 Introduction

### SEWTM

SEWTM is a disaggregate multi-modal transport model of South East Wales. The model comprises separate highway and public transport assignment models linked together with a variable demand model. The model was developed for Welsh Government with a 2015 base year, validated to WebTAG Unit M3.1 guidance. It has been designed to:

- Understand the current travel patterns in South East Wales and the performance of the transport system;
- Monitor changes in travel patterns over time;
- Predict future travel patterns and conditions on the transport network;
- Assess the impacts of possible interventions in the transport system in a consistent manner;
- Assess the impacts of land use changes such as new housing developments and employment locations in a consistent manner; and
- Provide inputs required for transport appraisals and business cases.

The model represents an average weekday, and for most purposes, outputs are divided into four time periods:

- AM peak between 0700 and 0930; peak hour assignment representing 0745-0845;
- Inter-peak (IP) between 0930 and 1530; average hour assignment;
- PM between 1530 and 1800; peak hour assignment representing 1630-1730; and
- Off-peak (OP) between 1800 and 0700; average hour assignment.

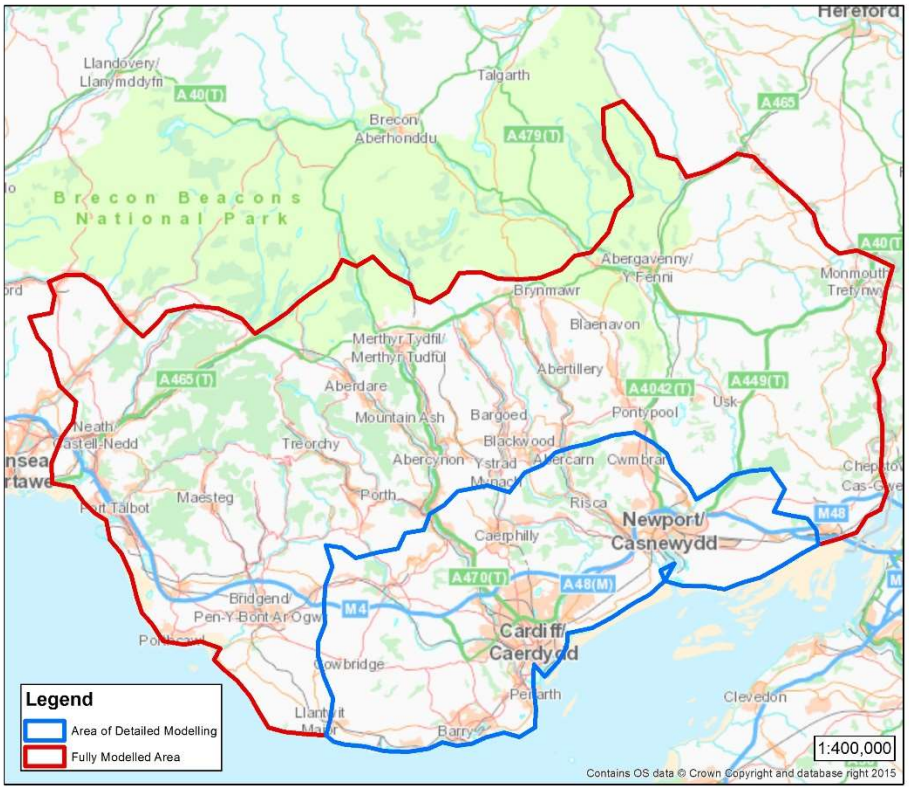
The following assignment user classes are included in the highway model:

- Car commute;
- Car business;
- Car other;
- LGV; and
- HGV.

The highway models utilise an equilibrium assignment which attempts to minimise path costs across all origin-destination (OD) pairs. Convergence is a measure of the proximity to an equilibrium solution; the highway model convergence meets guidance set out in WebTAG Unit M3.1.

SEWTM geographical coverage is shown in Figure 1. The Cardiff local authority area is within the Area of Detailed Modelling. This is the area of the transport model within which significant impacts of interventions are more certain. Within this area the model will represent all trips (demand), model zones are generally smaller than LSOAs, the transport network is detailed, and junction modelling is included.

**Figure 1: SEWTM modelled area**




Source: Mott MacDonald

### Method Overview

The transport modelling approach that has been adopted for this study balances the need to forecast the highway network impacts of a range of interventions with the need to maintain a proportionate approach to appraisal, taking account of the high-level nature of the study and the associated time and budget constraints. The full multi-modal Variable Demand Model (VDM) has been used to forecast the 2021 baseline situation given expected changes to population, employment and the highway/public transport networks. The highway assignment user classes have been split by EU standard compliant/non-compliant engine class using information provided by Ricardo, determined from 2018 Automatic Number Plate Recognition (ANPR) surveys.

### Clean Air Strategy Package Interventions

Clean Air Strategy Package 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.

**Table 1: Clean Air Strategy Package Intervention Methodologies**

| | | Description | Modelling Methodology |
|---|---|---|---|
| Package 1 | 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 | |
| | 3 | New 50mph speed limit on A4232 (Culverhouse Cross to Butetown Tunnels) | The representation of the affected section of the A4232 was changed from a national speed limit link type to a 50mph speed limit link type |
| Package 2 | 4 | Westgate Street mid-point closure to general traffic | The central section of Westgate Street was closed to all cars and goods vehicles to prevent through-movements whilst maintaining local access |
| | 5 | East side scheme, reducing through traffic movements on Station Terrace | Links were opened/closed as appropriate and junctions edited to reflect the proposed scheme. |
| | 6 | A48 St Mellons bus-based park and ride | For trips in nearby corridors with a trip end in the city centre, a proportion to be intercepted at the new P&R site was assumed, based upon evidence from existing sites. One of the trip ends for these trips was then reassigned from the city centre to the location of the P&R site. |
| | 7 | M4 J33 park and ride | As item 6, except that the number of trips to be intercepted was calculated using an assumed occupation level (broadly equivalent to current occupation of the East P&R site). |
| | 8 | Parking charges and controls, affecting vehicles with non-compliant engines. | UK government Joint Air Quality Unit (JAQU) guidance on option appraisal was used to provide estimates of the effect on trip making of implementing charging zones for non-compliant vehicles. A proportion of vehicles affected by increased parking charges was calculated using parking "event" data provided by Cardiff Council. Non-compliant vehicle trips were then moved to the compliant matrix, removed from the matrices altogether, or left unaltered accordingly. |
| Package 3 | 9 | A470 additional southbound traffic lane | Capacity constraints were removed at the merge node southbound of the junction with the A468. |
| | 10 | Nantgarw bus park and ride | As item 7. |

Source: Mott MacDonald

**Clean Air Zone Interventions**

Two clean air zone (CAZ) interventions have been modelled; a clean air zone covering cars, buses, coaches, and taxis, and a Class C clean air zone covering buses, coaches, taxis, and goods vehicles. These have also been assessed using the 2021 baseline as a starting point and applying trip matrix adjustments based upon JAQU guidance and set out in greater detail later in this note. Buses, coaches, and taxis are not explicitly modelled in the SEWTM highway networks and the effects on these types of vehicles have therefore not been included.

**Technical Note Structure**

The remainder of this note is structured as follows:

- Section 2 lists the SEWTM base year (2015) model outputs supplied to Ricardo for use in developing an initial base year air quality model;
- Section 3 sets out the approach and assumptions used in preparing 2021 baseline forecasts;
- Section 4 explains how the highway trip matrices have been divided into compliant / non-compliant engine standards for subsequent air quality modelling purposes; and
- Section 5 sets out the methods used for assessing Clean Air Strategy Package transport interventions on the highway network.
- Section 6 sets out the methods used for assessing the car-based CAZ.
- Section 7 sets out the methods used for assessing the goods vehicle-based CAZ.

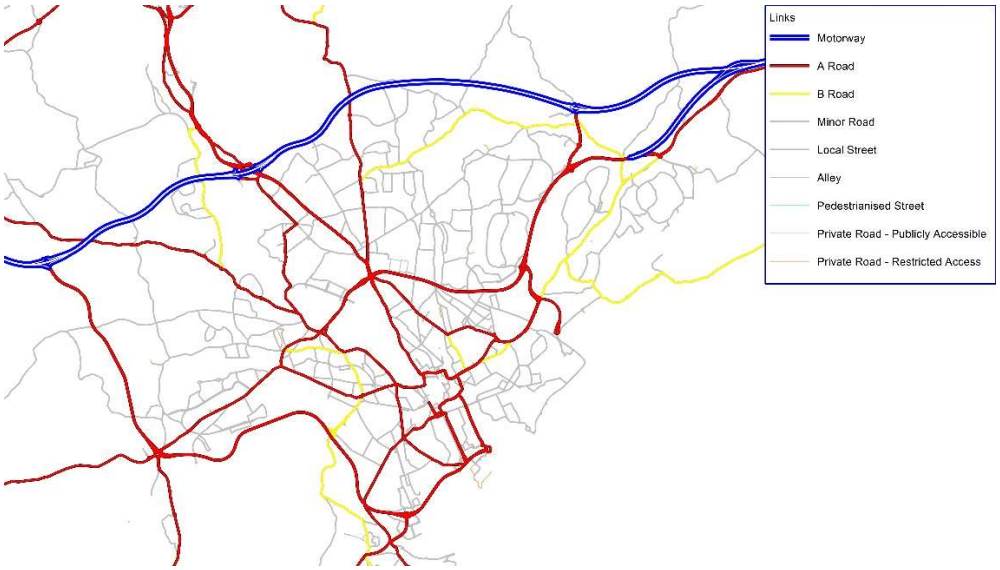
# 2 Base Model Outputs

SEWTM has been developed with a base year model representing 2015. To enable Cardiff Council's air quality consultants (Ricardo) to build a base year air dispersion model, the following outputs have been provided from the SEWTM base year highway models:

- Link and node structure in GIS shapefile format;
- Correspondence file which defines the relationship between SEWTM highway network links and the Ordnance Survey Integrated Transport Network (ITN) layer – the latter has been used by Ricardo to develop the air dispersion model;
- Highway link flows (vehicles per hour) at a time-period level for every modelled highway network link;
- Bus flows on each link;
- Modelled hour to time period factors, which allow for all-day traffic flows to be estimated;
- Traffic speeds on each modelled link; and
- Link information (number of lanes, single/dual carriageway etc).

The highway network level of detail contained in SEWTM for the Cardiff area is shown in Figure 2.

**Figure 2: SEWTM highway network in Cardiff area**




Source: Mott MacDonald

# 3 Preparing the 2021 Reference Case Forecast

The forecast year for this project is 2021, whereas the usual SEWTM forecast years are 2026 and 2036. A 2021 reference case VDM forecast has been prepared to provide a baseline scenario. Air quality measures have then been tested using this reference case forecast as a starting point.

**Demographic Scenario**

To enable a 2021 forecast to be carried out, a 2021 demographic scenario was prepared. Demographic inputs to SEWTM include (but are not limited to):

- Job and population forecasts for the whole of Great Britain;
- Detailed population forecasts for the fully modelled area; and
- Income data for the population in the fully modelled area.

The base year data used for SEWTM is derived from the 2011 Census, and a variety of other data sources. Experian data purchased in 2015 is used to provide growth for detailed demographic inputs at a Local Authority (LA) level. For the purposes of this project a 2021 baseline demographic scenario has been developed by interpolating between the 2015 and 2026 scenarios. This data was then adjusted to take account of explicitly modelled developments (both employment and housing), predominantly in the Cardiff LA. The developments shown in Table 2 have been explicitly modelled as new point zones with new network access arrangements, except for Cardiff Central Enterprise Zone, for which the additional population/jobs have been incorporated into existing model zones.

**Table 2: Explicitly modelled strategic developments in SEWTM, 2021**

| Strategic site | Dwellings | Employment | Adopted Housing Location | Demographic | Sample |
|---|---|---|---|---|---|
| Cardiff Central Enterprise Zone | 645 | 7206 | Century Wharf, Cardiff | | |
| Plasdwr, North West Cardiff | 1146 | - | De Clare Drive, Radyr | | |
| M4 Junction 33 (Site D/E) | 520 | - | De Clare Drive, Radyr | | |
| North East Cardiff (Site F) | 1006 | - | Pontprennau | | |
| St Edeyrns, Cardiff | 703 | - | Pontprennau | | |
| Ely Bridge, Cardiff | 650 | - | Pontprennau | | |
| Bay Point, Cardiff | 225 | - | Century Wharf, Cardiff | | |
| Glan-Llyn, Newport | 1160 | 1200 | Pontprennau | | |

Source: Mott MacDonald, based on information provided by Cardiff Council

The detailed demographic proportions for each new site (for example the proportion of self-employed workers) were taken from existing similar developments, as detailed above**.** Factors were calculated for each model input to apply to existing zones in the relevant LA, such that the model input totals in the final demographic scenario were controlled to those in the baseline interpolated scenario (at LA level).

**Highway and Public Transport Networks**

Highway and Public Transport (PT) networks have been adapted from existing model scenarios. As agreed with Cardiff Council, the highway networks have had the following schemes coded in addition to the 2015 base models:

- Cardiff Eastern Bay Link Phase 1;
- M4 Junction 32 Improvements (new through-junction link and traffic signals for M4 westbound to A470 northbound movements);
- M4 Junction 33 Improvements (new left-turn filter lane from M4 westbound off-slip to A4232);
- Removal of Severn Bridge tolls; and
- A4336 Five Mile Lane Road Quality Improvements.

The public transport networks represent the proposed KeolisAmey rail scenario at 2021 for the Core Valley Lines. This includes:

- A total of 4 trains per hour (tph) from Cardiff to each of Treherbert / Aberdare / Merthyr / Rhymney / Coryton;
- New direct services (2tph) from Treherbert / Aberdare / Merthyr into Cardiff Bay, as part of the 4tph total on each of these lines; and
- Some Aberdare services routed via the City Line so that the City Line is better connected to the wider rail network.

Access arrangements for the explicitly modelled development zones have been coded as outlined in Table 3.

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**Table 3: Access Arrangements for Explicitly Modelled Strategic Developments in SEWTM, 2021**

| Name | Highway Access | Public Transport Access |
|---|---|---|
| Cardiff Central Enterprise Zone | No additional access arrangements, existing zones/access used. | |
| Plasdwr, North West Cardiff | Access split between Llantrisant Road A4119 at the north and Pentrebane Road at the south | Doubled frequency of bus service 122 on the Robin Hill (Creigiau) – Cardiff section of the route, to provide a service into Cardiff every 10 minutes |
| M4 Junction 33 | Access via Llantrisant Road A4119 at the North | |
| North East Cardiff | Access split between St Mellons Road at the north and Pentwyn Road by high school at the south | New bus service, 20km/h, 4 services per direction per hour, route: University Hospital – Gabalfa – Llanishen – NE Cardiff development – Pontprennau Asda/St. Edeyrns (and reverse) |
| St Edeyrns, Cardiff | Access via new arm on existing A4232 roundabout at Pontprennau | |
| Ely Bridge, Cardiff | New access road, Sanatorium Road, which meets Cowbridge Road West at a signalized junction to the north-west and Broad Street at a signalised junction to the south-east | No additional PT arrangements |
| Bay Point, Cardiff | Access via roundabout at Morrisons site | No additional PT arrangements |
| Glan-Llyn, Newport | Access via roundabouts onto A4810 | New X74 and X74s bus services / bus service extensions |

### WebTAG Parameters

The WebTAG databook issued by the Department for Transport (DfT) defines Values of Time (VOT) and Vehicle Operating Costs (VOC) for use in transport modelling and scheme appraisal. Parameter values are generally given by year and updates to the databook are released several times annually. As is usual modelling practice, forecast values have been derived using the base year values available at the time the model was validated, and applying growth in parameter values from the latest version of the databook. For base year values the Autumn 2015 version of the databook was used. For forecast parameter growth the May 2018 databook has been used.

### Exogenous Demand and Speed Forecasts

SEWTM does not produce growth forecasts for HGVs, LGVs, or external-external car trips passing through the model area. The representation of growth in such trips in the forecast highway models is based on the DfT Road Traffic Forecasts (RTF) which provide growth to apply to the 2015 base year trip matrices. The RTF version used in initial SEWTM forecasting was the 2015 (scenario 1) version. Late on during this model application the RTF 2018 version of the data (the first issued since 2015) became publicly available. However, due to time constraints it has not been possible to incorporate the updated forecasts in the modelling.

It is known that the 2018 version of RTF forecasts significantly lower growth in HGV and LGV movements (with a modest increase in car travel) compared to the 2015 version. As such it is recommended that any further modelling work on this project incorporates the 2018 version of RTF.

RTF 2015 has also been used to derive changes in fixed link speeds in the external model area.

# 4 Vehicle Type Split

This section details how the highway matrices have been split into compliant and non-compliant (Euro Standard engine) categories derived from ANPR data.

**Data Source**

Cardiff Council arranged for ANPR cameras to be installed temporarily at 12 locations in Cardiff, covering 21 traffic movements, 19 of which are included in the transport model coverage. Over the course of a week in May 2018, number plates were captured by the cameras and linked to a DVLA database containing various emission-related vehicle characteristics. A series of checks has been carried out on the ANPR data to check that it is sensible. Air dispersion modellers at Ricardo processed the data and carried out forecasting and back-casting exercises (for 2015 and 2021) to provide the Euro-emissions class compliant/non-compliant split for each of the 19 movements, split by vehicle type (HGV, LGV, car).

It was considered whether to implement separate splits for different OD pairs, based upon the ANPR survey sites they passed through. However, it was found that there was little variation in the proportion of compliant vehicles between the surveyed movements, particularly for the movements with the highest volumes. Additionally, it was noted that a significant percentage of OD pair paths passing through one survey site also passed through another, meaning that this would be practically difficult to implement. For reasons of simplicity therefore, a volume-weighted average of the proportion of compliant vehicles was taken for each time period and vehicle class, and all OD pairs were split based upon this proportion. The percentage of compliant vehicles for each of the time period-vehicle type combinations is shown for 2021 in Table 4. The 2015 results are not presented in this report since the air dispersion model was calibrated using unsplit transport model data.

**Table 4: Proportion of Compliant Vehicles by Time Period and Vehicle Type (2021)**

| | Car | HGV | LGV |
|---|---|---|---|
| AM | 74.5% | 79.3% | 45.7% |
| IP | 74.6% | 79.1% | 45.3% |
| PM | 74.6% | 79.0% | 45.6% |
| OP | 73.8% | 79.0% | 45.3% |

Source: ANPR Data

Following vehicle split implementation in the assigned 2021 reference case networks, the same output types, as provided for the base year models (see Section 2), were provided to Ricardo for air dispersion modelling.

# 5 Testing Clean Air Strategy Package (CASAP) Measures

This section details the methodologies used to assess the impact of CASAP air quality measures on the highway network. Given the high-level nature of the study and the associated time and budget constraints, CASAP measures have been assessed using the highway model only, post-VDM.

The CASAP measures were divided into three packages for testing, CASAP 1, CASAP 2, and CASAP 3, with CASAP 2 including all of the measures from CASAP 1 along with additional measures, and with CASAP 3 including all of the measures from CASAP 2 and CASAP 1 along with additional measures. The measures were as follows:

CASAP 1:

1. Active travel packages, covering two areas close to the city centre;
2. Cycling programme to end of 2020; and
3. New 50mph speed limit on A4232 (Culverhouse Cross to Butetown Tunnels).

CASAP 2:

All CASAP 1 measures above plus:

4. Westgate Street mid-point closure to general traffic;
5. East side scheme, reducing through traffic movements on Station Terrace;
6. A48 St Mellons park and ride;
7. M4 J33 park and ride; and
8. Parking charges and controls, affecting vehicles with non-compliant engines.

CASAP 3:

All CASAP 1 and CASAP 2 measures above plus:

9. A470 additional southbound traffic lane; and
10. Nantgarw bus park and ride.

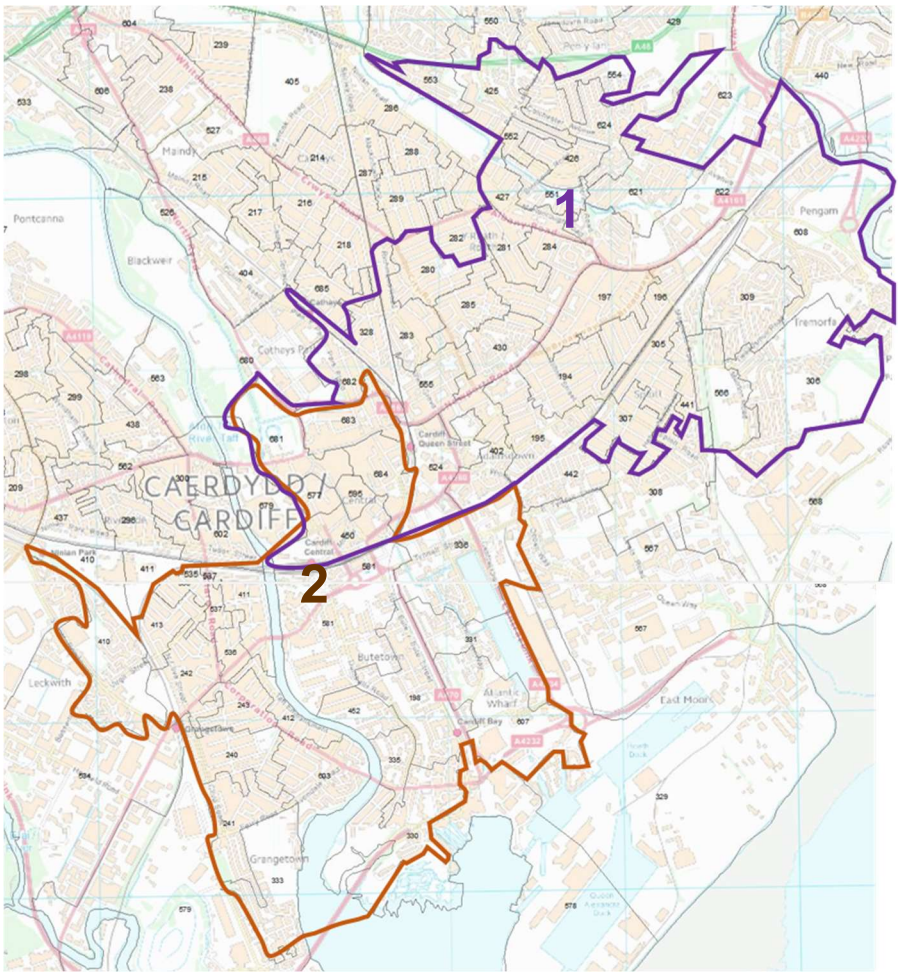
Within each package, the measures were applied in the order listed above. The rest of this section details the specific measures and the methodology used to model them.

**Active Travel Packages**

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 3, 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 compliance type.

**Figure 3: 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). Pre-CASAP 1 mode shares and active travel package reduction factors are shown for areas 1 and 2 in Table 5 and Table 6 respectively.

**Table 5: 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 6: 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 |

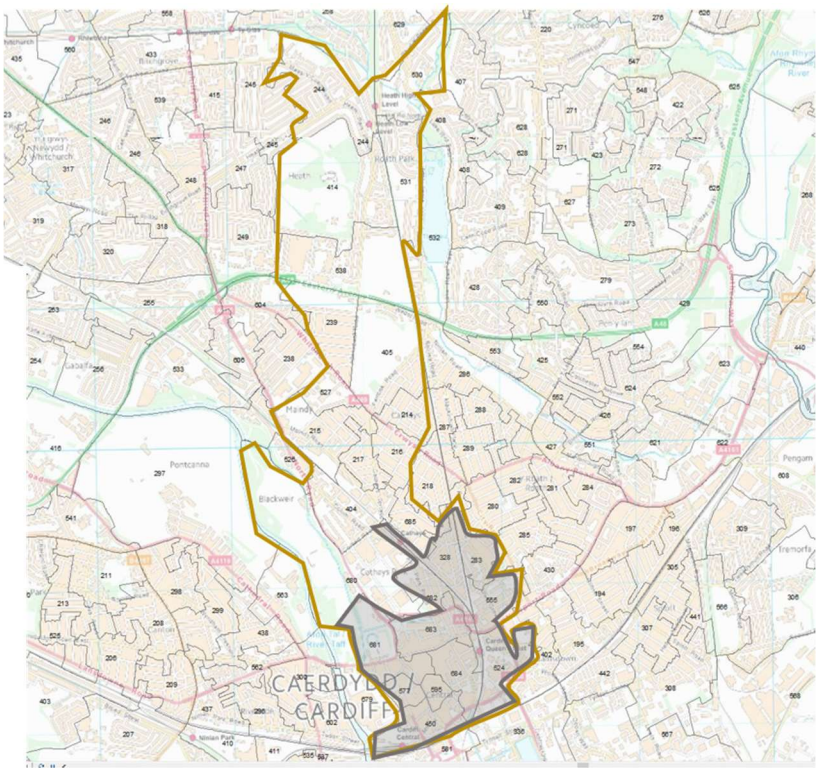
Source: Mott MacDonald

### 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 4). 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 4: Cycling Programme Area**




Source: Mott MacDonald

Pre-CASAP 1 car driver mode shares and reduction factors are shown for the cycle package in Table 7.

**Table 7: 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

### New 50mph Speed Limit on A4232 (Culverhouse Cross to Butetown Tunnels)

The section of the A4232 shown in Figure 5, between the A48 at Culverhouse Cross and the Butetown Tunnels, was changed from a national speed limit link type to a 50mph speed limit link type.

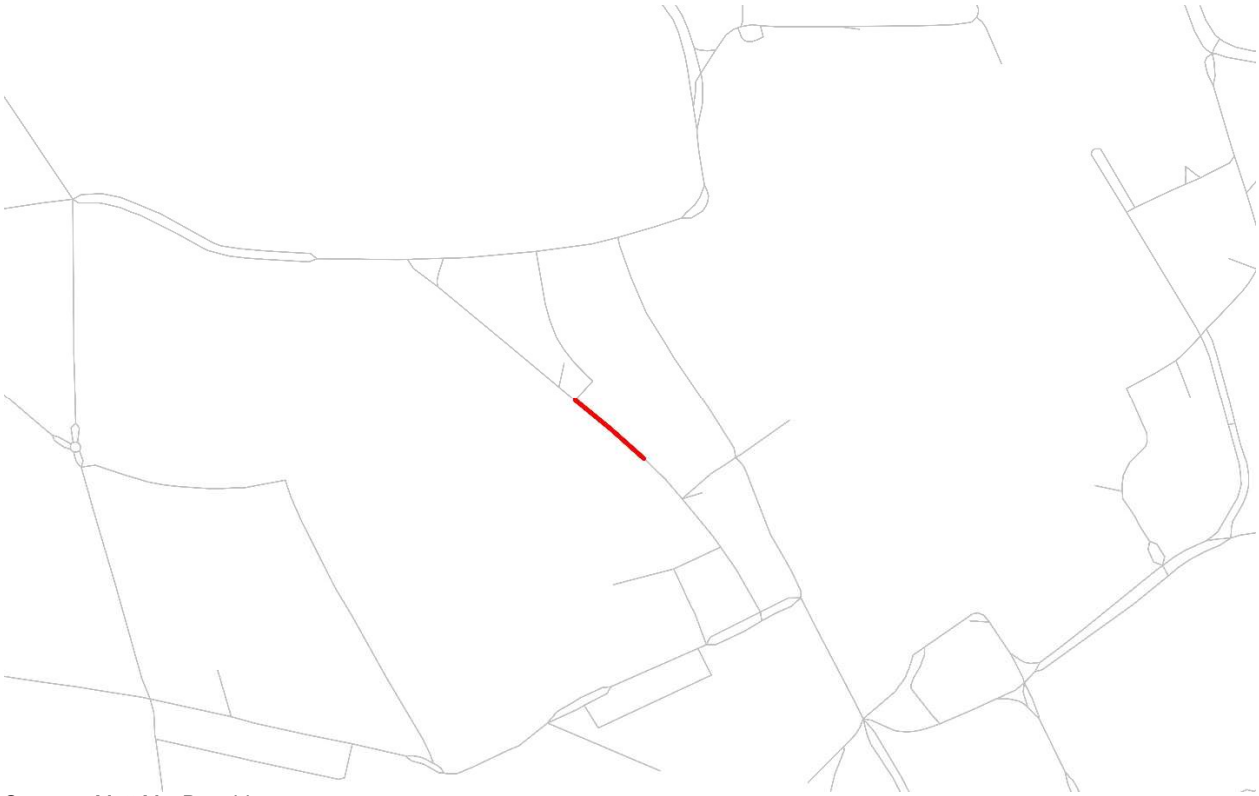
**Figure 5: 50mph Section of A4232**

Source: Mott MacDonald

### Westgate Street Mid-Point Closure to General Traffic

Through-movements were prevented from using Westgate Street by closing the link highlighted in Figure 6. Access for car trips to all city centre model zones has been maintained, although trips may need to re-route to avoid the closure.

**Figure 6: Closure of Westgate Street**

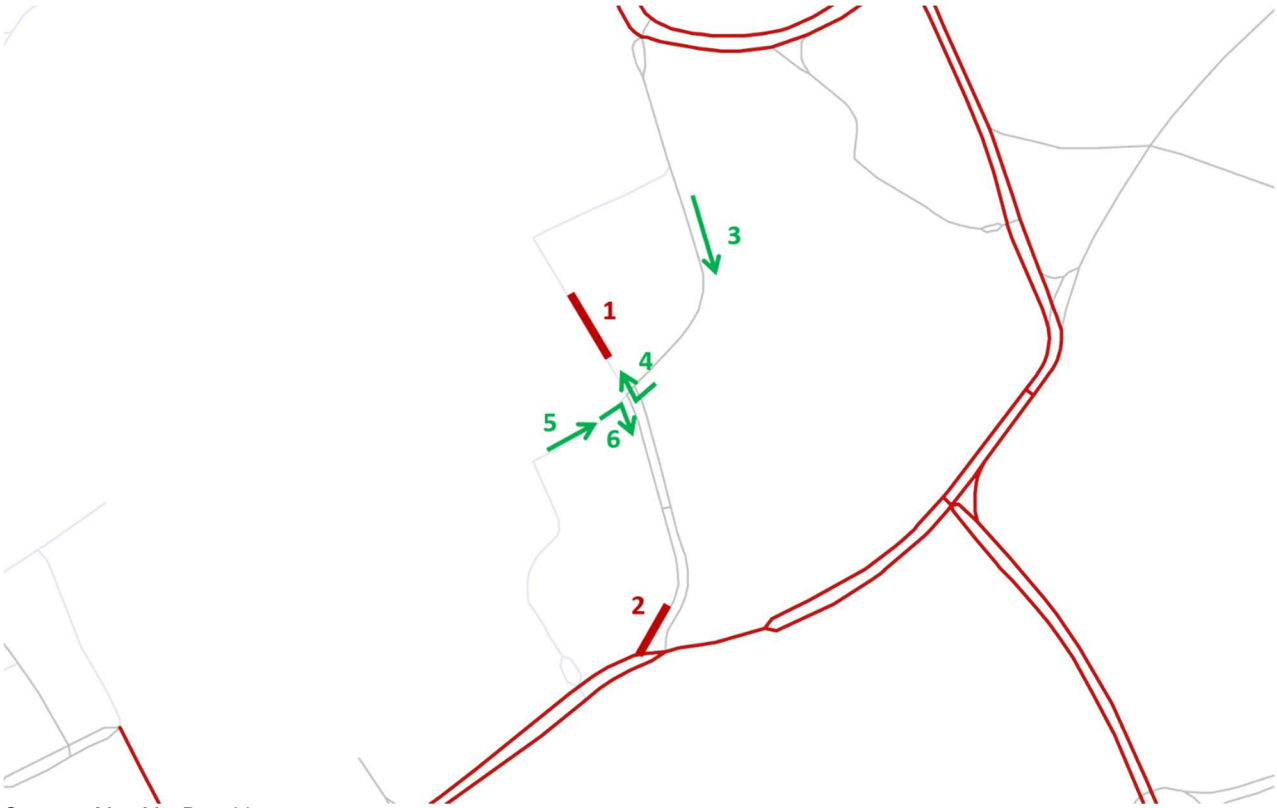


Source: Mott MacDonald

### East Side Scheme

The highway network edits presented in Figure 7 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 movements, to which general traffic restrictions are not expected to apply. Bus movements in the highway model are represented as link and turn preloads only, and as such the alterations detailed below were applied to all highway assignment classes.

**Figure 7: East Side Scheme**




Source: Mott MacDonald

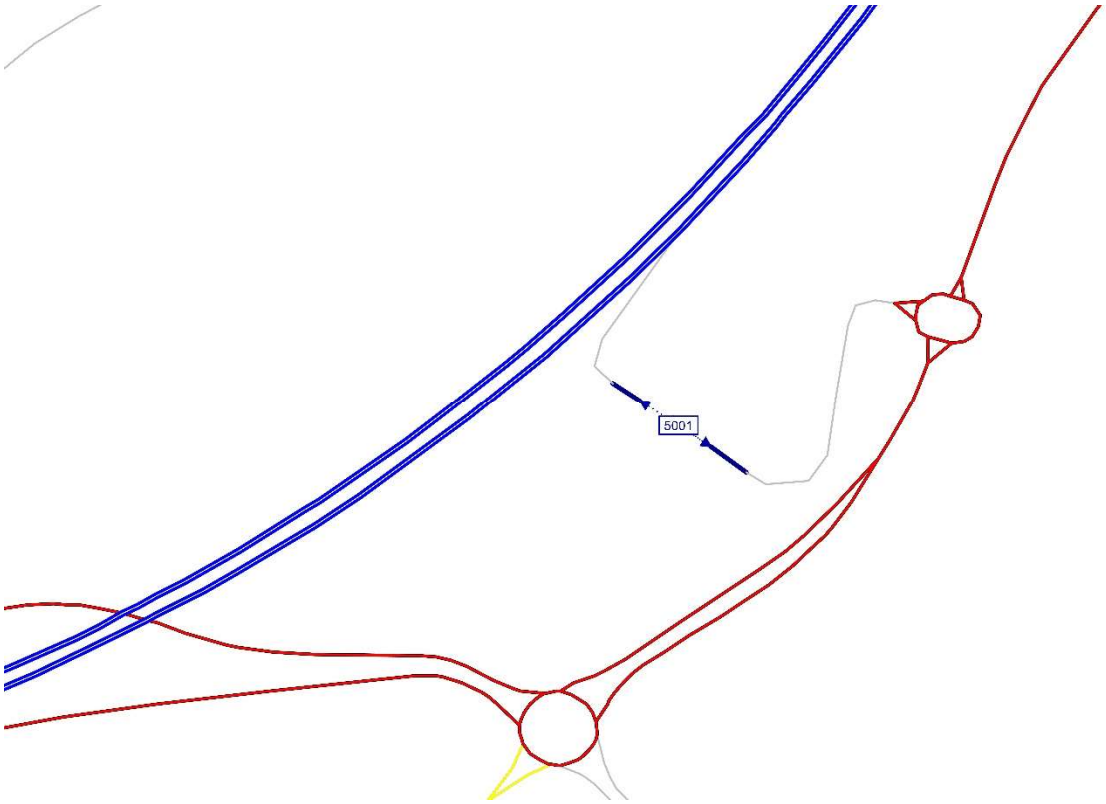
Annotations:

1. Closure of Churchill Way southbound between North Edward Street and Guildford Street.
2. Closure 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 implemented at traffic signals for traffic from Guildford Street.
5. Bridge Street set to one way eastbound.
6. Mandatory right turn implemented at traffic signals for traffic from Bridge Street.

### A48 St Mellons Park and Ride

The broad methodology for this measure was to identify the car trips with a trip end in Cardiff City Centre which might switch to park and ride for the final section of their journey. A proportion of these journeys then had one end of the trip altered to the location of the park and ride site, rather than the city centre. The network coding implemented to allow access to the new site is shown in Figure 8. Inbound and outbound access was allowed from A48 by way of a new roundabout junction. Inbound-only access was allowed from the A48(M) westbound.

**Figure 8: A48 Park and Ride Network Coding**

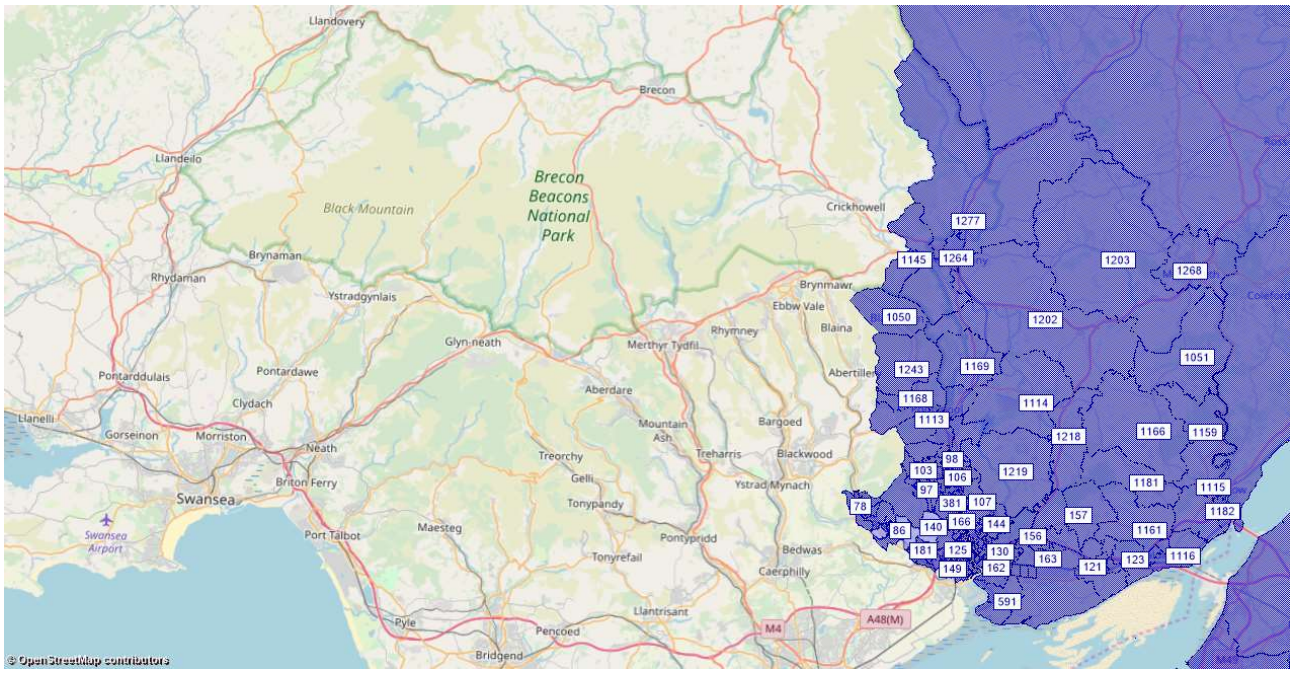



Source: Mott MacDonald

Evidence indicates that the Cardiff East park and ride site removes approximately 3% of inbound car trips on A48 Eastern Avenue during the AM peak hour. It was therefore assumed that, due to the time advantage that would be afforded by new bus lanes along the A48 Eastern Avenue (but to avoid double counting with the existing Cardiff East site), an additional park and ride would remove a further 2% of inbound flow on the A48(M) / A48 during the AM peak period.

All AM peak car trips with an origin in the park and ride catchment area (see Figure 9) and a destination in the park and ride bus route corridor (see Figure 10) were identified as ‘in scope’ trips, the OD pair was reversed for the PM peak hour.

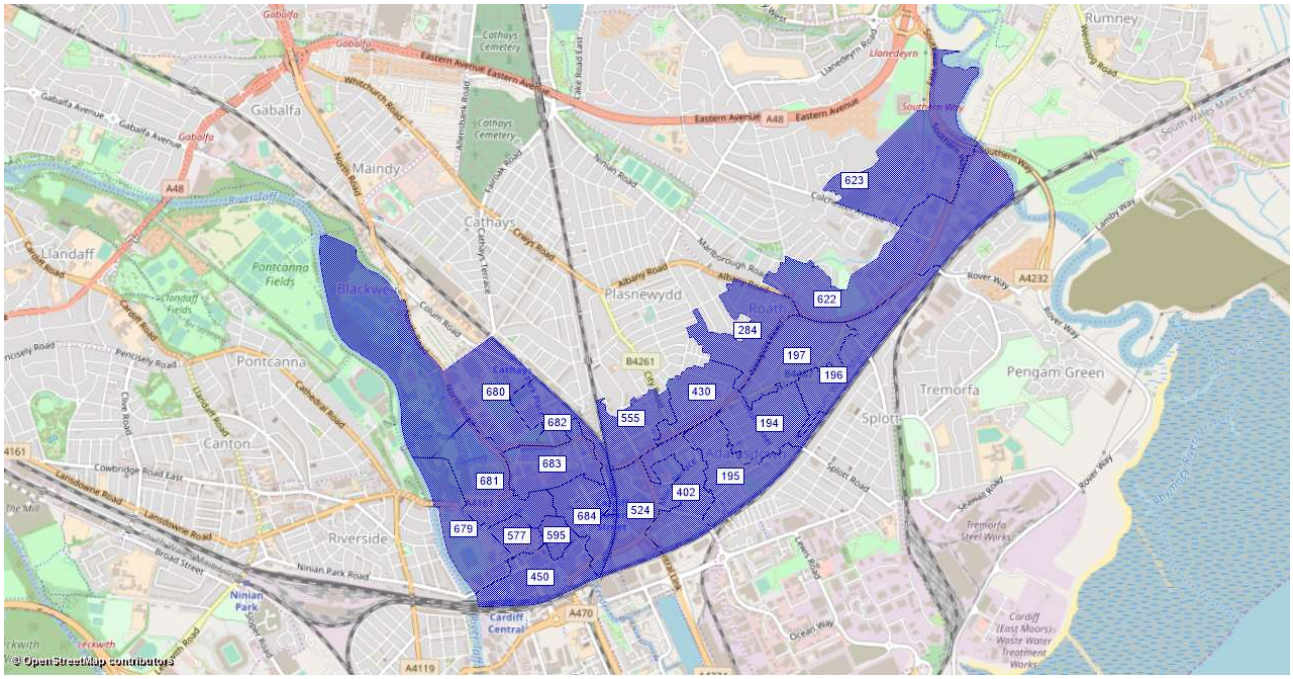
**Figure 9: Origin Scope Area for A48 St Mellons Park and Ride**




Source: Mott MacDonald

*N.B. Also included* in the *catchment area but not shown are the Welsh unitary authorities of Denbighshire, Flintshire, and Wrexham, all of England, and all of Scotland.*

**Figure 10: Destination Scope Area for A48 St Mellons Park and Ride**




Source: Mott MacDonald

The number of trips identified as 'in scope' are shown by journey purpose and vehicle emissions class in Table 8. A total of approximately 83 'in scope' trips have been identified in the AM peak hour.

**Table 8: A48 Park & Ride Peak Hour 'in scope' Trips Extracted from 2021 Highway Network Models**

| Journey Purpose | Vehicle Emission Compliance Category | In Scope Trips | |
|---|---|---|---|
| | | AM | PM |
| Business | Compliant | 6.1 | 4.0 |
| | Non-compliant | 2.1 | 1.4 |
| Commute | Compliant | 46.7 | 26.0 |
| | Non-compliant | 15.9 | 8.9 |
| Other | Compliant | 8.9 | 18.8 |
| | Non-compliant | 3.1 | 6.4 |
| TOTAL | | 82.8 | 65.5 |

Source: Mott MacDonald

The number of vehicles passing the location of the park and ride site in the inbound direction on the A48(M) and A48 were extracted from the 2021 AM peak hour highway network, as shown in Table 9. A total of 2% of the AM peak hour link flows on the A48 and A48(M) were assumed to switch to park and ride, with the absolute number reversed for the PM peak, applied proportionally across the 'in scope' trip OD pairs. This amounted to 60.4% of the AM 'in scope' trips and 76.4% of the PM 'in scope' trips. For the AM peak the destination of these trips was set to the park and ride site location. Conversely, for the PM peak the origin of these trips was set to the park and ride site location.

**Table 9: AM Peak Hour Link Flows for A48(M) + A48 Extracted from Highway Network Models**

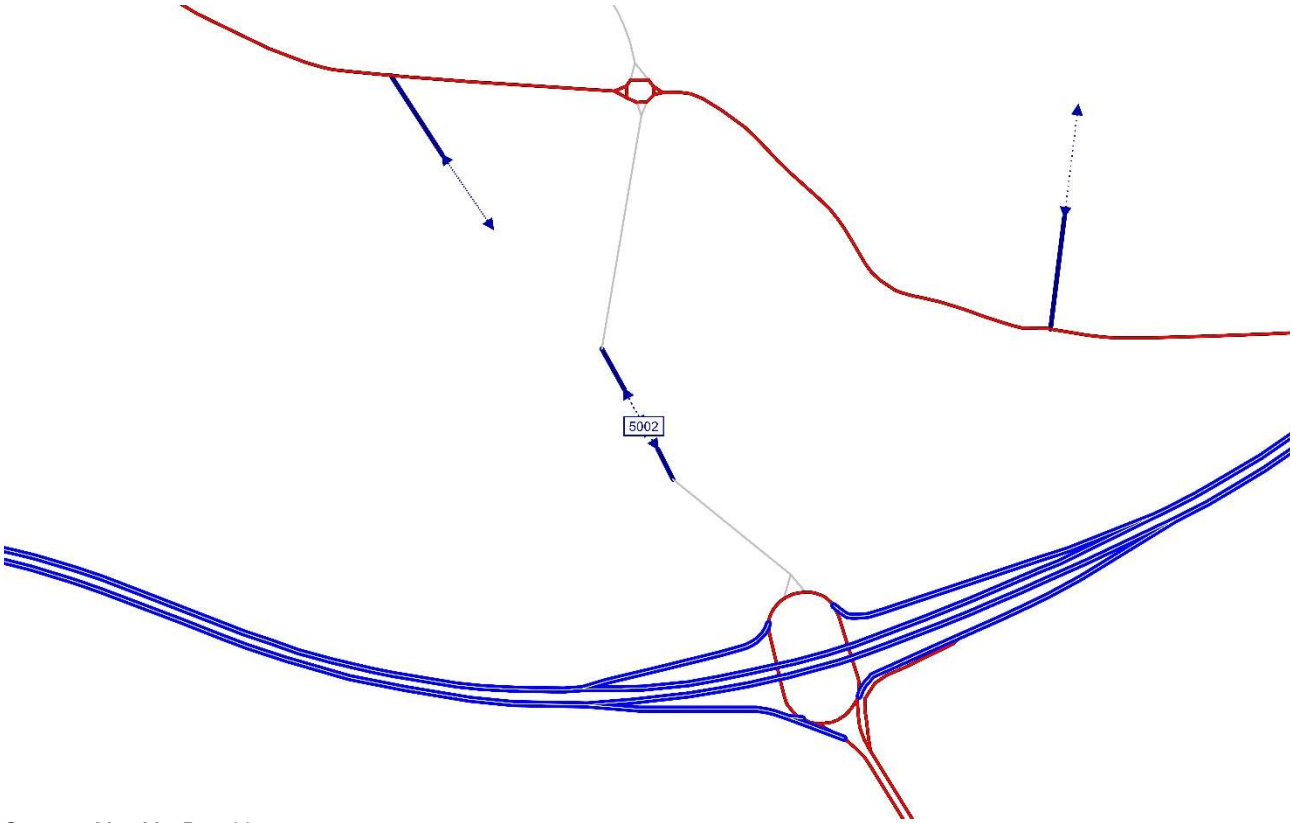
| Journey Purpose | Vehicle Emission Compliance Category | A48(M) + A48 Link Flow |
|---|---|---|
| Business | Compliant | 174.4 |
| | Non-compliant | 60.3 |
| Commute | Compliant | 1286.9 |
| | Non-compliant | 439.2 |
| Other | Compliant | 401.5 |
| | Non-compliant | 138.0 |
| TOTAL | | 2500.3 |
| 2% OF TOTAL – use new P&R site | | 50.0 |

Source: Mott MacDonald

### M4 J33 Park and Ride

A similar modelling approach to the A48 park and ride site was followed for the new M4 J33 site. The network coding implemented to allow access to this location is shown in Figure 11. Access is possible from both M4 J33 and the A4119. Through-movements via the park and ride site are not allowed.

**Figure 11: M4 J33 Park and Ride Network Coding**

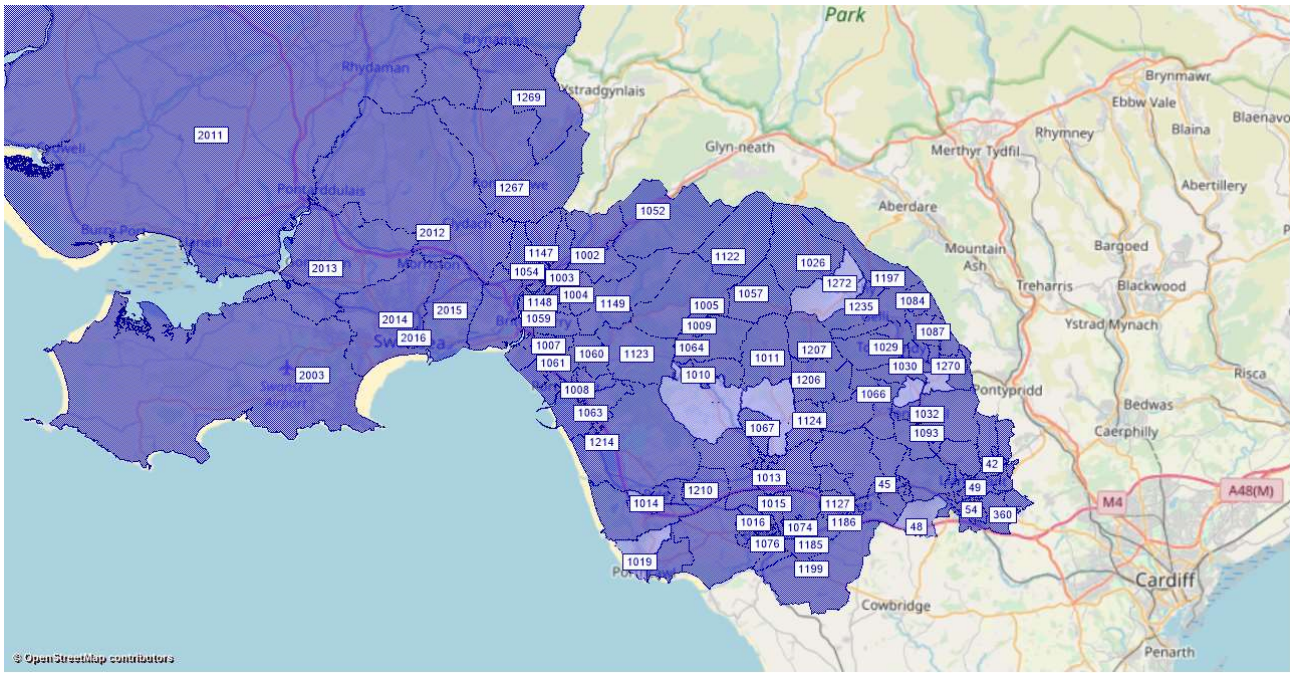



Source: Mott MacDonald

The M4 J33 site car park is expected to have a capacity of 1000 vehicles. It was assumed that in the early years of operation (such as 2021) approximately a third of spaces (330) would be occupied by the end of the AM peak period, equating to approximately 150 cars arriving during the AM peak hour.

All AM peak car trips with an origin in the park and ride catchment area (see Figure 12) and a destination in the park and ride bus route corridor (see Figure 13) were identified as ‘in scope’ trips, the OD pair was reversed for the PM peak hour.

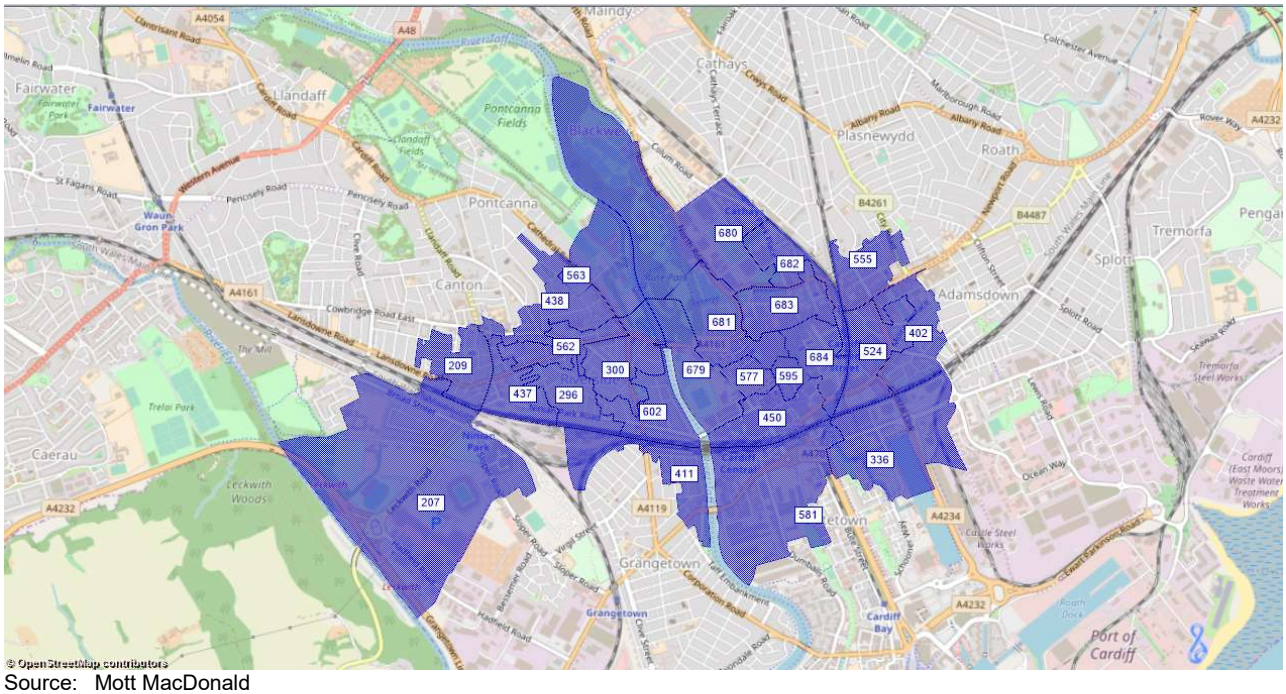
**Figure 12: Origin Scope Area for M4 J33 Park and Ride**




Source: Mott MacDonald

*N.B. Also included* in the *catchment area but not shown are the Welsh unitary authorities of Carmarthenshire, Ceredigion, and Pembrokeshire.*

**Figure 13: Destination Scope Area for M4 J33 Park and Ride**




Source: Mott MacDonald

The number of trips identified as 'in scope' are shown by journey purpose and vehicle emissions class in Table 10. A total of approximately 245 trips were identified as 'in-scope' in the AM peak hour.

**Table 10: M4 J33 Park & Ride Peak Hour 'in scope' Trips Extracted from 2021 Highway Network Models**

| Journey Purpose | Vehicle Emission Compliance Category | In Scope Trips | |
|---|---|---|---|
| | | AM | PM |
| Business | Compliant | 42.4 | 29.0 |
| | Non-compliant | 14.6 | 10.1 |
| Commute | Compliant | 115.4 | 87.7 |
| | Non-compliant | 39.4 | 29.9 |
| Other | Compliant | 24.8 | 68.3 |
| | Non-compliant | 8.5 | 23.2 |
| TOTAL | | 245.0 | 248.2 |

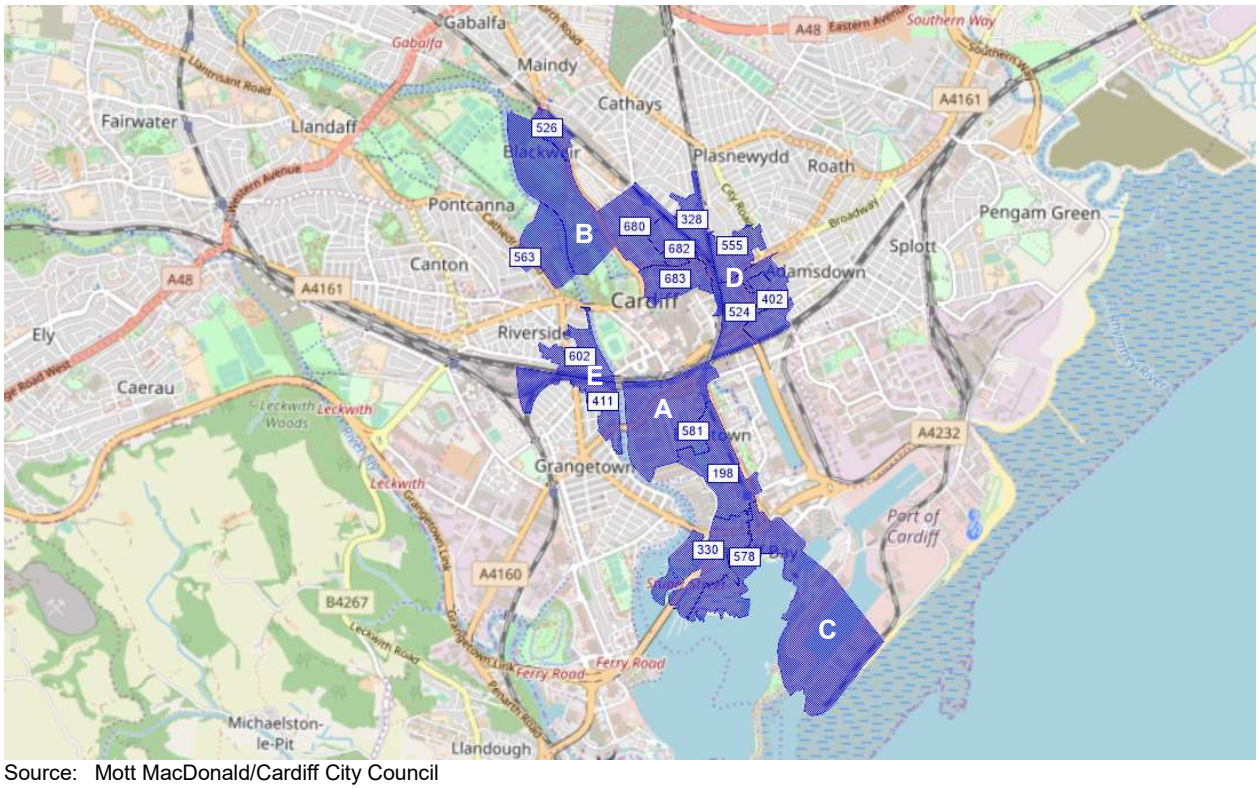
Source: Mott MacDonald

The switch to park and ride of 150 vehicles was applied proportionally across the 'in scope' trips OD pairs in both the AM peak hour and PM peak hour. This amounted to 61.2% of the AM 'in scope' trips and 60.4% of the PM 'in scope' trips. For the AM peak the destination of these trips was set to the park and ride site location. Conversely, for the PM peak the origin of these trips was set to the park and ride site location.

### Parking Charges and Controls

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 to non-compliant vehicles only. The model zones containing car parking spaces for which an additional levy would apply are shown in Figure 14.

**Figure 14: Zones Containing Council Car Parking Spaces in Cardiff city centre**




Source: Mott MacDonald/Cardiff City Council

UK government Joint Air Quality Unit (JAQU) guidance on option appraisal provides estimates of the effect on trip making of implementing charging zones for non-compliant vehicles. These estimates are developed from stated preference surveys and assume a £12.50 per day charge.

For the Cardiff parking charge assessment, it is assumed that the effect of additional parking charges would be analogous with clean air zone charging evidence, with the exception of trips avoiding the clean air zone which, for parking charges in Cardiff, are assumed to find alternative parking locally. It is also assumed that (for any daily charges less than £12.50) the proportion of drivers altering their trip making in a given manner is linearly related to cost. At this stage the effect of different income levels in South East Wales has not been considered. The assumed responses of drivers affected by the charge are shown in Table 11.

**Table 11: Driver Response for Affected Vehicles**

| User Choice | Replace Vehicle | Cancel Trip | Change Mode | Avoid Zone | Pay Charge |
|---|---|---|---|---|---|
| £12.50 Charge | 22.0% | 16.0% | 23.0% | 23.0% | 16.0% |
| £5.00 Charge (Calculated) | 8.8% | 6.4% | 9.2% | 9.2% | 66.4% |
| RELEVANT TOTALS FOR MODELLING | Trips to be switched to compliant vehicles matrix | Trips to be removed from highway matrices | | Trips unaltered by measure | |
| | 8.8% | 6.4% + 9.2% = 15.6% | | 9.2% + 66.4% = 75.6% | |

Source: JAQU Guidance/Mott MacDonald

Data provided by Cardiff Council was used to identify the number of AM peak hour 'parking events' taking place in Council-owned or managed spaces in each relevant zone. The zones were then grouped geographically (labelled A-E in Figure 14) to ensure that the number of observed peak hour parking events

was proportionate to the number of trips with a destination in that group of zones. The number of AM non-compliant peak hour car trips to each zone that would use spaces affected by additional parking charges, assuming non-compliant and compliant vehicles use affected spaces proportionally, was calculated, as shown in Table 12. Consequently, the proportion of overall car trips to grouped zones affected in a given manner is shown in Table 13.

**Table 12: Assumed Parking Events by Compliance Category**

| Grouped Zones | Group | A | B | C | D | E |
|---|---|---|---|---|---|---|
| | Zone IDs | 198, 581 | 328, 526, 563, 680, 682, 683 | 330, 578 | 402, 524 555 | 411, 602 |
| Peak Hour Trips to Grouped Zone | Compliant | 920.7 | 1515.0 | 396.3 | 736.0 | 153.3 |
| | Non-Compliant | 315.1 | 518.3 | 135.6 | 251.8 | 52.4 |
| Peak Hour Parking Events (Source: Cardiff Council) | Total | 125 | 731 | 176 | 247 | 136 |
| | Compliant | 93.1 | 544.7 | 131.1 | 184.04 | 101.34 |
| | Non-Compliant | 31.9 | 186.4 | 44.9 | 63.0 | 34.7 |

Source: Cardiff City Council/Mott MacDonald

**Table 13: Percentage of Trips Affected by Zone Group**

| Change | Group | A | B | C | D | E |
|---|---|---|---|---|---|---|
| Trips to be switched to compliant vehicles | | 0.9% | 3.2% | 2.9% | 2.2% | 5.8% |
| Trips to be removed from matrices | | 1.6% | 5.6% | 5.2% | 3.9% | 10.3% |
| Trips unaltered by additional measures | | 97.5% | 91.2% | 91.9% | 93.9% | 83.9% |

Source: Mott MacDonald

The trips switching to an alternative mode or not travelling were then removed from the non-compliant matrix, whereas the trips switching to using compliant vehicles were reallocated from the non-compliant to the compliant matrix.

The process was carried out for the PM matrices using the same percentage shifts as shown above and reversing OD pairs such that the locations shown in Figure 8.1 are taken as the origin zones. The consequent matrix total changes are shown in Table 14.

**Table 14: Changes in OD Matrix Totals due to Parking Charges**

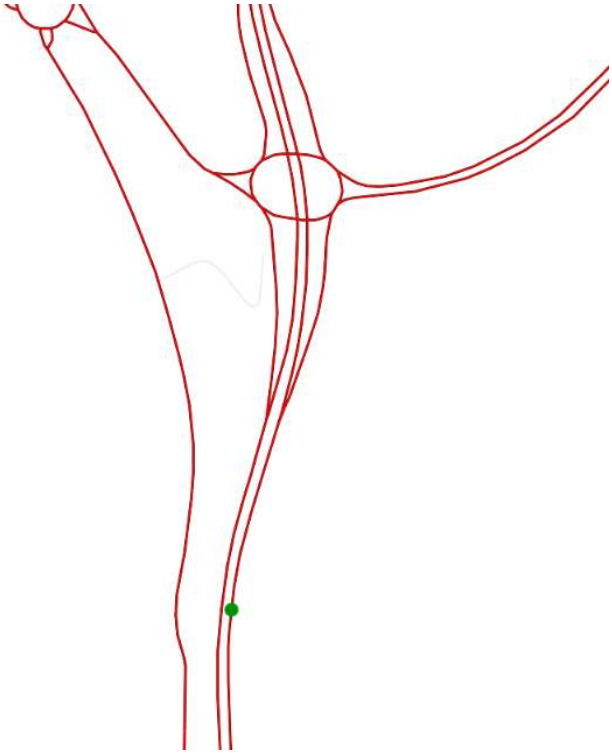
| Matrix | | | Pre-Charge Implementation | Post-Charge Implementation | Percentage Change |
|---|---|---|---|---|---|
| AM | Business | Compliant | 12300.4 | 12304.1 | 0.03% |
| | | Non-Compliant | 4252.4 | 4242.2 | -0.24% |
| | Commute | Compliant | 67992.3 | 68009.3 | 0.02% |
| | | Non-Compliant | 23211.3 | 23164.3 | -0.20% |
| | Other | Compliant | 53883.0 | 53894.1 | 0.02% |
| | | Non-Compliant | 18433.5 | 18402.7 | -0.17% |
| PM | Business | Compliant | 7311.2 | 7312.8 | 0.02% |
| | | Non-Compliant | 2556.8 | 2552.3 | -0.17% |
| | Commute | Compliant | 48593.6 | 48603.6 | 0.02% |
| | | Non-Compliant | 16562.7 | 16535.0 | -0.17% |
| | Other | Compliant | 88210.2 | 88228.1 | 0.02% |
| | | Non-Compliant | 29970.7 | 29921.2 | -0.17% |

Source: Mott MacDonald

### A470 Additional Southbound Traffic Lane

Given the strategic nature of the model, the specific traffic issues with respect to weaving are not represented in this location. A pragmatic approach has been taken towards the modelling of the extra Southbound traffic lane, and the capacity restriction at the southbound merge node (which contributes delay as the road is reduced from 3 to 2 lanes) south of the junction with the A468, as shown in Figure 15, has been removed.

**Figure 15: Southbound Merge Node Removed on A470**



Source: Mott MacDonald

### Nantgarw Bus Park and Ride

The broad methodology for this measure was to identify the car trips with a trip end in Cardiff City Centre (along a narrow strip of zones centred on the A470 south of the junction with the A48 – Mynachdy Park) which might switch to park and ride for the final section of their journey. A proportion of these journeys then had one end of the trip altered to the location of the park and ride site, rather than the city centre. The network coding implemented to allow access to the new site with the intended layout and connector location is shown in Figure 16.

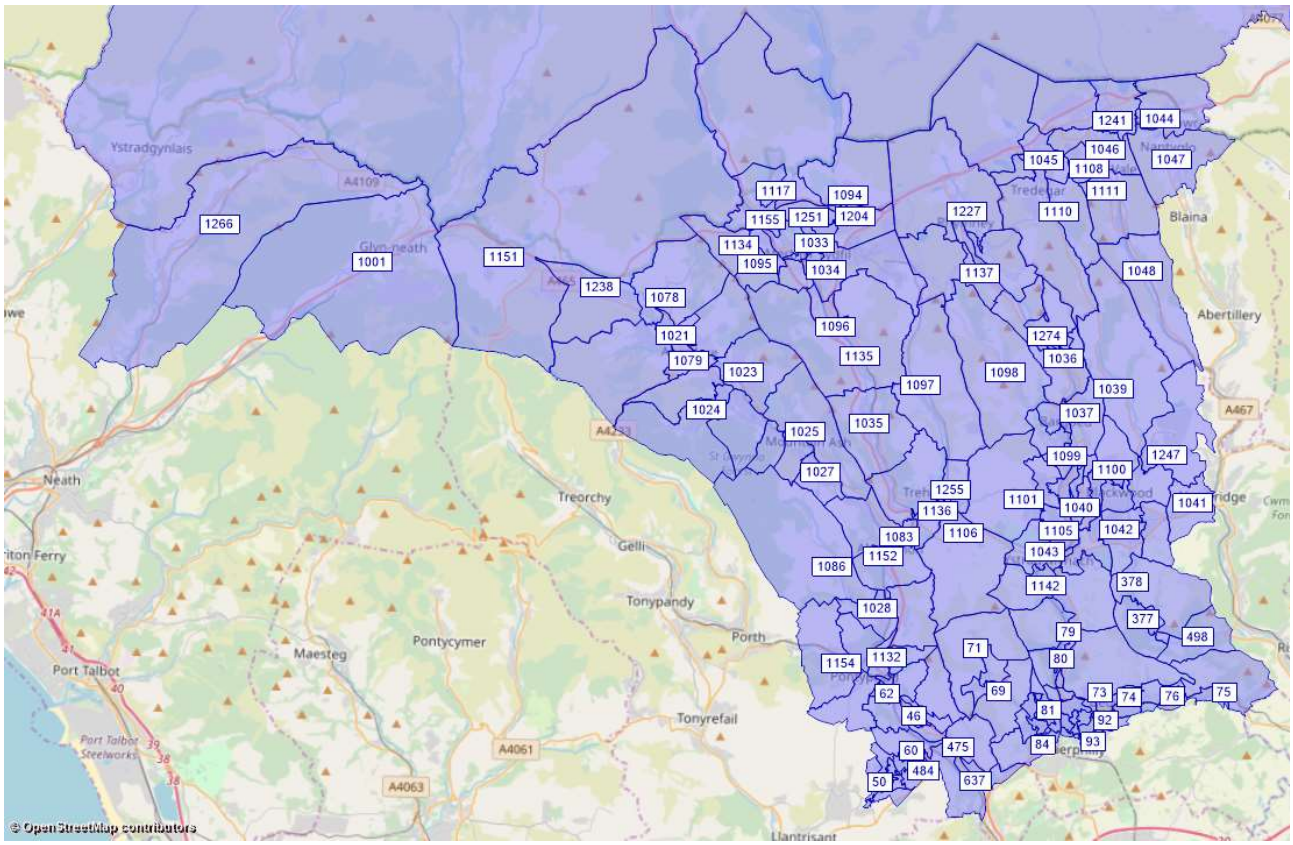
**Figure 16: Nantgarw Bus Park and Ride Network Coding**


Source: Mott MacDonald

The new car park site is expected to have capacity of 1000 vehicles. It was assumed that in the early years of operation (such as 2021) approximately a quarter of spaces (250) would be occupied by the end of the AM peak period, equating to approximately 114 cars arriving during the AM peak hour.

All AM peak car trips with an origin in the park and ride catchment area (see Figure 17) and a destination in the park and ride bus route corridor (see Figure 18) were identified as 'in scope' trips, the OD pair was reversed for the PM peak hour.

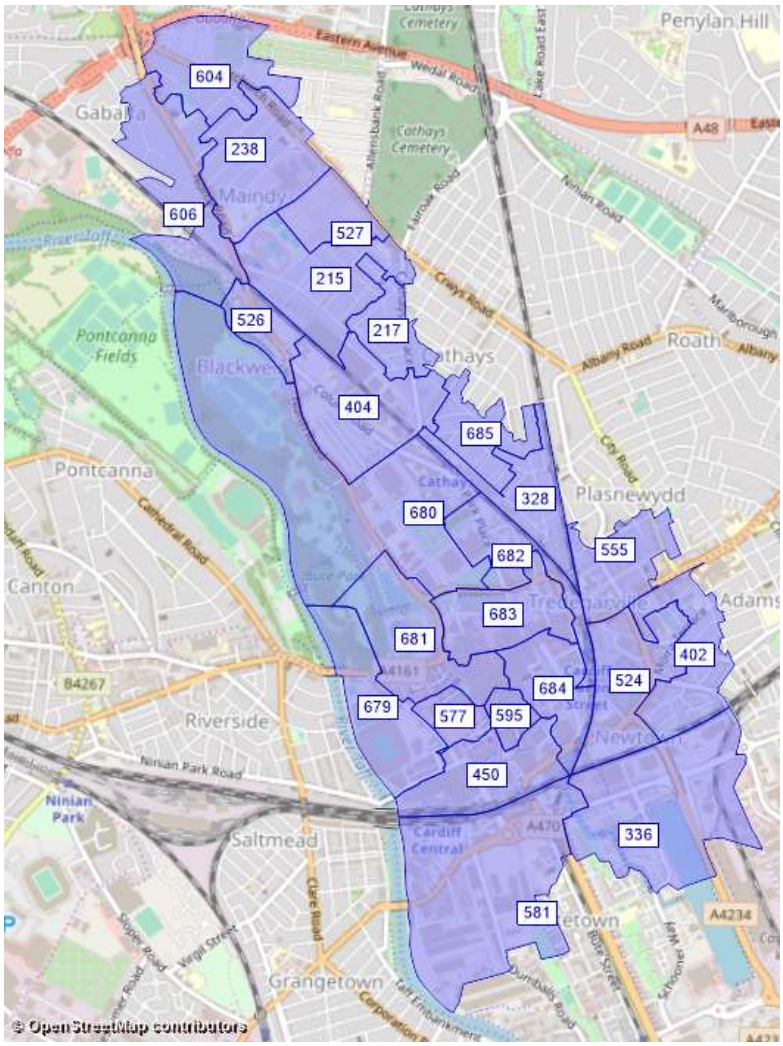
**Figure 17: Origin Scope Area for Nantgarw Bus Park and Ride**




Source: Mott MacDonald

*N.B. Also included in the catchment area but not shown are the Welsh unitary authorities of Conwy, Gwynedd, Isle of Anglesey, and Powys.*

**Figure 18: Destination Scope Area for Nantgarw Bus Park and Ride**




Source: Mott MacDonald

The number of trips identified as 'in scope' are shown by journey purpose and vehicle emissions class in Table 15. A total of approximately 227 trips were identified as 'in-scope' in the AM peak hour.

**Table 15: M4 J33 Park & Ride Peak Hour 'in scope' Trips from 2021 Highway Network Models**

| Journey Purpose | Vehicle Emission Compliance Category | In Scope Trips | |
|---|---|---|---|
| | | AM | PM |
| Business | Compliant | 24.0 | 10.5 |
| | Non-compliant | 8.1 | 3.6 |
| Commute | Compliant | 119.6 | 66.9 |
| | Non-compliant | 39.9 | 22.3 |
| Other | Compliant | 26.8 | 55.5 |
| | Non-compliant | 8.9 | 18.4 |
| TOTAL | | 227.3 | 177.2 |

Source: Mott MacDonald

The switch to park and ride of 114 vehicles was applied proportionally across the 'in scope' trips OD pairs in both the AM peak hour and PM peak hour. This amounted to 50.0% of the AM 'in scope' trips and 64.2% of the PM 'in scope' trips. For the AM peak the destination of these trips was set to the park and ride site location. Conversely, for the PM peak the origin of these trips was set to the park and ride site location.

# 6 Car-Based Clean Air Zone

This section details the methodology used to assess the impact of the car-based CAZ on the highway network. Given the high-level nature of the study and the associated time and budget constraints, this assessment has been undertaken by making adjustments to the highway demand matrices and networks, post-VDM.

Two scenarios were modelled whereby the CAZ charge was assumed to be a £10 or £5 per day levy, applicable to non-compliant cars only. The CAZ boundary is shown below in Figure 19.

JAQU guidance on option appraisal provides estimates of the effect on trip making of implementing charging zones for non-compliant vehicles. These estimates are developed from stated preference surveys on the London Ultra Low Emission Zone and assume a £12.50 per day charge.

For the car-based CAZ assessment, it has been assumed that the response of travellers beginning or ending their trips in the CAZ is analogous to the responses in this evidence, except for trips avoiding the clean air zone which are assumed to find alternative parking locally (note that this methodology assumes spaces are available). This is because the stated preference surveys upon which the JAQU evidence is based were specific to a much larger clean air zone, and in the modelled situation travellers are much more likely to park nearby and continue by foot to their ultimate destination. It is also assumed that (for any daily charges less than £12.50) the proportion of drivers altering their trip making in a given manner is linearly related to cost. At this stage the effect of different income levels in South East Wales has not been considered. For trips which pass through the CAZ, but do not have an origin or destination location within it, tolls have been coded directly onto links entering the zone and the response is calculated by the highway assignment algorithms. This is because it is much easier for drivers to avoid the smaller Cardiff CAZ in comparison to the CAZ presented in the stated preference survey used for JAQU evidence.

The responses to the implementation of a charge from non-compliant vehicles with a trip end in the CAZ were assumed as shown in Table 16, as per JAQU guidance. The required manipulation applied to highway matrices is also shown.

**Table 16: Response of Non-Compliant vehicle users to the imposed charge, as per JAQU guidance**

| Required Matrix Manipulation | Response Type | Response at £12.50 | Linearly Interpolated Response | |
|---|---|---|---|---|
| | | | At £10.00 | At £5.00 |
| Move from Non-Compliant to Compliant | Replace Vehicle | 64.0% | 51.2% | 25.6% |
| Remove from Non-Compliant | Cancel Trip | 7.0% | 5.6% | 2.8% |
| | Change Mode | 11.0% | 8.8% | 4.4% |
| Alter Trip End Zone for Non-Compliant | Avoid Zone | 11.0% | 8.8% | 4.4% |
| Leave Unchanged | Pay Charge | 7.0% | 25.6% | 62.8% |

Source: JAQU Guidance/Mott MacDonald

The matrix manipulation was undertaken as a four-stage process:

1. Move trips from Non-Compliant to Compliant (affects both compliant and non-compliant matrices)
2. Remove trips from Non-Compliant (affects non-compliant matrices only)
3. Change Non-Compliant destination zones for inbound trips
4. Change Non-Compliant origin zones for outbound trips

Following stage 2, the matrix totals remain unchanged throughout the remainder of the process. The overall change to the number of trips is shown below in Table 17.

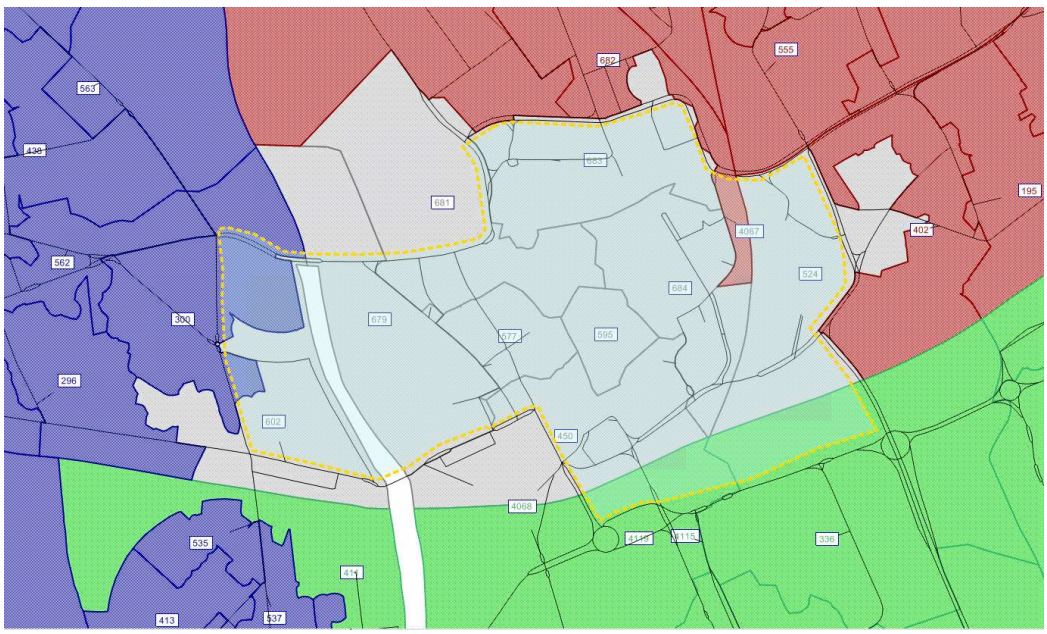
**Table 17: Total change in 'in scope' trips by time-period and by charge value**

| User Class | Vehicle Class | £10 Matrix Total Response (veh) | | | | £5 Matrix Total Response (veh) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | AM | IP | OP | PM | AM | IP | OP | PM |
| Car Business | Compliant | 85.32 | 51.48 | 15.58 | 43.06 | 42.66 | 25.74 | 7.79 | 21.53 |
| | Non-Compliant | -109.32 | -65.95 | -19.96 | -55.18 | -54.66 | -32.98 | -9.98 | -27.59 |
| Car Commute | Compliant | 307.32 | 73.88 | 22.38 | 222.40 | 153.66 | 36.94 | 11.19 | 111.20 |
| | Non-Compliant | -393.75 | -94.66 | -28.68 | -284.95 | -196.88 | -47.33 | -14.34 | -142.48 |
| Car Other | Compliant | 280.19 | 490.63 | 149.90 | 472.54 | 140.09 | 245.32 | 74.95 | 236.27 |
| | Non-Compliant | -358.99 | -628.63 | -192.06 | -605.44 | -179.49 | -314.31 | -96.03 | -302.72 |
| **TOTAL** | | -189.23 | -173.25 | -52.84 | -207.56 | -94.62 | -86.62 | -26.42 | -103.78 |

Source: Mott MacDonald

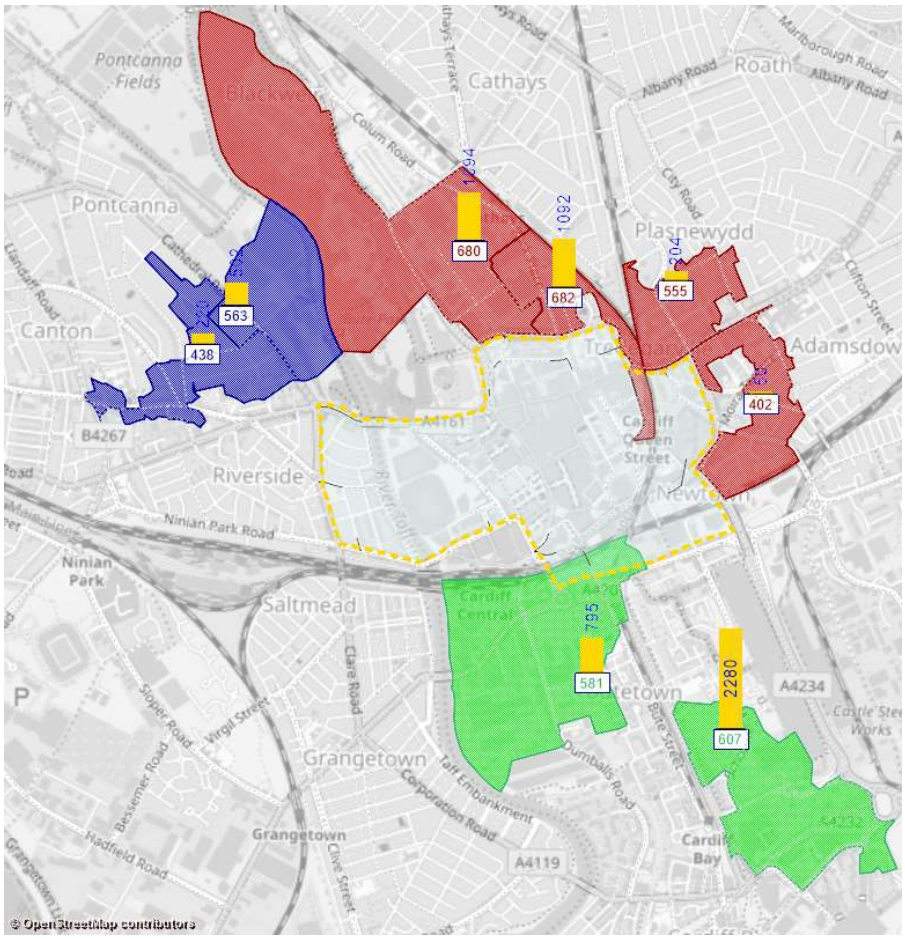
To implement steps 3 and 4, analysis of the routes taken to and from the network zones matching most closely with the CAZ (shown below in Figure 19 in grey) was undertaken for the AM time period. This analysis was used to inform the creation of three sectors (henceforth referred to as North, South, and West (partially shown below as red, green, and blue respectively) and corresponding to the alternate trip-end network zones shown in Figure 20.

**Figure 19: Clean Air Zone (yellow dashed territory) overlaid over defined sectors**




Source: Mott MacDonald

**Figure 20: Identified external parking zones close to the clean air zone, coloured by sector**




Source: Mott MacDonald

Car park location data was examined, and the above eight zones were identified as nearby parking zones where people may choose to park and walk into the Clean Air Zone. The trip redistribution for each of the three sectors was carried out proportionally to the total number of council owned / managed spaces in each of the above zones (as shown by yellow bars).

**Table 18: Proportion of inbound / outbound trips from and to each sector to be rerouted to each zone**

| Sector | Zone Number | Parking Zone Considerations | |
|---|---|---|---|
| | | Spaces | Proportion |
| North | 402 | 50 | 2.05% |
| | 555 | 204 | 8.36% |
| | 680 | 1094 | 44.84% |
| | 682 | 1092 | 44.75% |
| South | 581 | 795 | 25.85% |
| | 607 | 2280 | 74.15% |
| West | 438 | 220 | 30.47% |
| | 563 | 502 | 69.53% |
| **TOTAL** | | **6237** | |

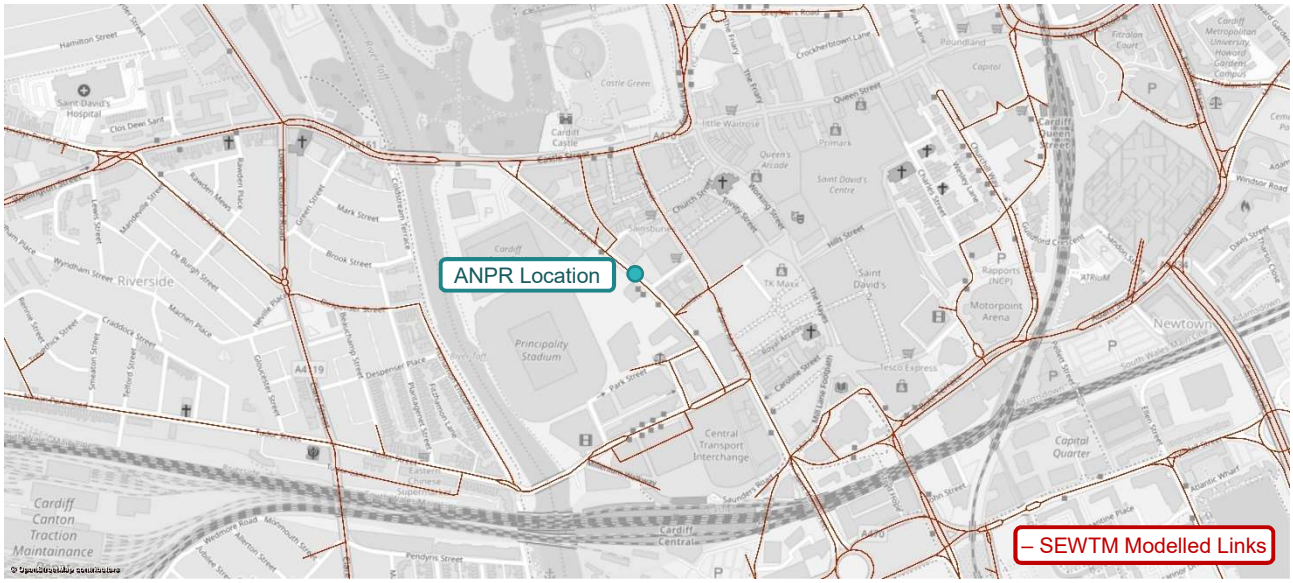
Source: Mott MacDonald

### ANPR Analysis and Application of Tolls

As noted above, tolls were applied on links entering the CAZ to account for through-trips. Since through-traffic may enter the CAZ multiple times in a single day (the period over which the charge is applicable), it was necessary to apply a reduction factor to the applied toll so that the effect of rerouting is not overestimated.

Automatic Number Plate Recognition (ANPR) data produced by Tracsis plc on behalf of Ricardo was analysed. Consideration was not made towards separating taxis from cars or treating travel purposes independently, and the only ANPR site close to the clean air zone is located at Westgate Street, shown below:

**Figure 21: Location of counts for relevant ANPR data**




Source: Mott MacDonald

ANPR data from Fridays and weekends was excluded, and as such, the days shown in Table 19 were considered. The average number of daily through-trips in either direction for a vehicle passing the site is also displayed.

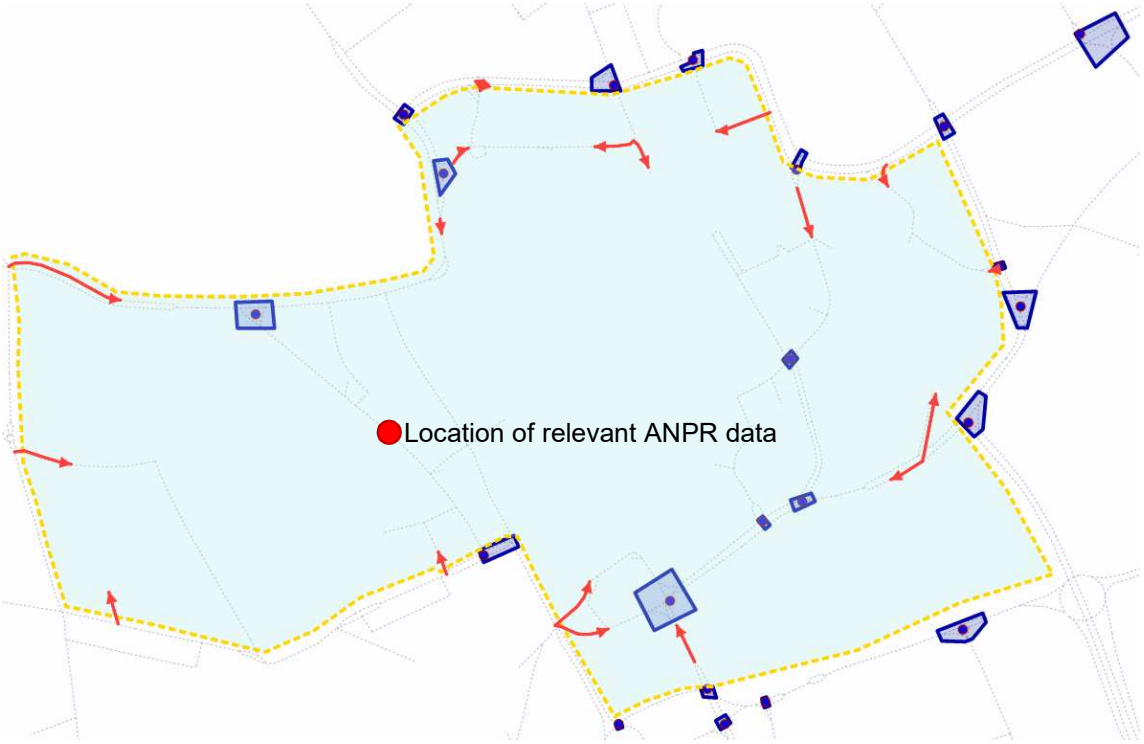
**Table 19: Weighted mean toll reduction factor from ANPR data on Westgate Street**

| Weekday | Weekday Mean | Date | Date Mean |
|---|---|---|---|
| Tuesday | 1.94 | 08/05/2018 | 1.94 |
| Wednesday | 2.09 | 02/05/2018 | 2.18 |
| | | 09/05/2018 | 2.00 |
| Thursday | 2.06 | 03/05/2018 | 2.06 |
| **WEIGHTED MEAN** | **2.03** | | |

Source: Mott MacDonald

The application of this reduction factor corresponds to an applied toll of £2.46 or £4.92 instead of £5.00 or £10.00 respectively. The links to which the above tolls were applied are identified as the inbound links to the clean air zone only, shown in red below in Figure 22.

**Figure 22: SEWTM links to which tolls are applied in relation to the boundary of the CAZ**




Source: Mott MacDonald

# 7 Goods Vehicle-Based Clean Air Zone

This section details the methodology used to assess the impact of the goods vehicle-based CAZ on the highway network. Given the high-level nature of the study and the associated time and budget constraints, this assessment has been undertaken by adjusting the highway demand matrices and networks, post-VDM.

The CAZ charge was assumed to be a £10 or £50 per day levy for LGVs and HGVs respectively, applicable to non-compliant vehicles only. The same boundary as for the car-based CAZ was assumed.

JAQU guidance on option appraisal provides estimates of the effect on trip making of implementing charging zones for non-compliant vehicles, including LGVs and HGVs. These estimates are developed from stated preference surveys on the London Ultra-Low Emission Zone and assume a £12.50 per day charge or £100 per day charge for LGVs and HGVs respectively.

The interpretation of the JAQU guidance was the same for goods vehicles as for cars, with the exceptions that the JAQU-specified vehicle kilometres response was used rather than the vehicle response (due to the nature of the way that goods vehicles operate) and that goods vehicles which avoided the zone were removed from the matrices and their goods assumed to be incorporated into other deliveries.

The responses to the implementation of a charge from non-compliant vehicles with a trip end in the CAZ were assumed as shown in Table 20, as per JAQU guidance. The required manipulation applied to highway matrices is also shown.

**Table 20: Non-Compliant goods vehicle (GV) response to the imposed charges, as per JAQU guidance**

| Required Matrix Manipulation | Response Type | LGV Response at £12.50 | HGV Response at £100.00 | Linearly Interpolated Response | |
|---|---|---|---|---|---|
| | | | | LGV at £10.00 | HGV at £50.00 |
| Move from GV Non-Compliant to GV Compliant | Replace Vehicle | 64.0% | 83.0% | 51.2% | 41.5% |
| Remove from GV Non-Compliant | Cancel Trip | 6.0% | 4.0% | 4.8% | 2.0% |
| | Avoid Zone | 8.0% | 4.0% | 6.4% | 2.0% |
| Move from LGV Non-Compliant to Car Other | Change Mode | 2.0% | 0.0% | 1.6% | 0.0% |
| Leave Unchanged | Pay Charge | 20.0% | 9.0% | 36.0% | 54.5% |

Source: JAQU Guidance/Mott MacDonald

The matrix manipulation was undertaken as a three-stage process:

1. Move trips from Non-Compliant to Compliant (affects both compliant and non-compliant matrices)
2. Move trips from Non-Compliant LGVs to Car Other (compliant and non-compliant proportionally)
3. Remove trips from Non-Compliant (affects non-compliant matrices only)

After this process the following overall change to the number of trips is noted in Table 21.

**Table 21: Total change in 'in scope' trips by time-period and by charge value**

| User Class | Vehicle Class | Time-Period | | | |
|---|---|---|---|---|---|
| | | AM | IP | OP | PM |
| Car Other | Compliant | 2.71 | 2.93 | 0.85 | 2.50 |
| | Non-Compliant | 0.93 | 0.99 | 0.30 | 0.85 |
| HGV | Compliant | 15.68 | 13.31 | 3.94 | 8.66 |
| | Non-Compliant | -17.20 | -14.60 | -4.32 | -9.49 |
| LGV | Compliant | 116.25 | 125.45 | 36.77 | 107.38 |
| | Non-Compliant | -145.32 | -156.81 | -45.96 | -134.22 |
| **TOTAL** | | **-26.94** | **-28.73** | **-8.42** | **-24.32** |

Source: Mott MacDonald

### ANPR Analysis and Application of Tolls

As noted above, tolls were applied on links entering the CAZ to account for through-trips. Since goods vehicles may enter the CAZ multiple times in a single day (the period over which the charge is applicable), it was necessary to apply a reduction factor to the applied toll so that the effect of rerouting is not overestimated.

Automatic Number Plate Recognition (ANPR) data produced by Tracsis plc on behalf of Ricardo was analysed. The only site close to the clean air zone is located on Westgate Street, as shown in the previous section.

ANPR data from Fridays and weekends was excluded, and as such, the following days were considered, with the average number of daily returns in either direction per passing vehicle also displayed.

**Table 22: Weighted mean toll reduction factor from ANPR data on Westgate Street**

| Weekday | HGVs | | | LGVs | | |
|---|---|---|---|---|---|---|
| | Weekday Mean | Date | Date Mean | Weekday Mean | Date | Date Mean |
| Tuesday | 1.74 | 08/05/2018 | 1.74 | 1.57 | 08/05/2018 | 1.57 |
| Wednesday | 1.60 | 02/05/2018 | 1.65 | 1.65 | 02/05/2018 | 1.65 |
| | | 09/05/2018 | 1.55 | | 09/05/2018 | 1.64 |
| Thursday | 1.74 | 03/05/2018 | 1.71 | 1.57 | 03/05/2018 | 1.61 |
| **WEIGHTED MEAN** | **1.68** | | | **1.61** | | |
| **COST PER VEHICLE** | **£50.00** | | | **£10.00** | | |
| **FACTORED COST** | **£29.73** | | | **£6.22** | | |

Source: Mott MacDonald

The tolls were applied to the same links as those for the car-based CAZ.