Welsh Government

EFFECTIVENESS REVIEW

Consideration of interventions on the Welsh Government Trunk Road and Motorway Network for Nitrogen Dioxide reduction

Yn gweithio ar ran
Llywodraeth Cymru
Working on behalf of the
Welsh Government

70040135
JANUARY / FEBRUARY 2018

PUBLIC

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1 INTRODUCTION

1.1 CONTEXT

1.1.1. The European Union Ambient Air Quality Directive (2008/50/EC) sets legally binding limits for concentrations of certain air pollutants in outdoor air, termed 'limit values'. The Directive requires that Member States report annually on air quality within zones designate under the Directive and, where the concentration of pollutants in air exceeds limit values, to develop air quality plans that set out measures in order to attain the limit values.

1.1.2. The Directive is transcribed into Welsh legislation via the Air Quality Standards (Wales) Regulations 2010. The regulations designate Welsh Ministers as the competent authority for the purposes of the Directive and place duties on Welsh Ministers to draw up and implement air quality plans in Wales.

1.1.3. The only limit values that the UK currently fails to meet are those set in respect of nitrogen dioxide (NO_2), with the greatest impacts seen at roadside locations. The UK Government published its Air Quality Plan for tackling roadside NO_2 concentrations in July 2017[1]. The UK Plan included zone plans for all four Welsh zones[2] which comprised measures proposed by Welsh Government and local authorities to improve roadside air quality[3].

1.1.4. The Welsh zones are currently projected to achieve compliance within the limit values in 2020 (Swansea), 2021 (North Wales), 2022 (Cardiff) and 2026 (South Wales). Exceedances of the limit values are primarily related to emissions from road transport.

1.1.5. This review of the likely effectiveness of potential measures forms an integral part of Welsh Government's work and has been used to inform the measure selection process within the WelTAG appraisal process.

1.1.6. Across Wales, road transport accounts for 28.5% of emissions of NO_X, with the majority of emissions coming from passenger cars and other light duty vehicles[4] (Table 1).Heavy duty vehicles contribute a lower proportion of emissions than across the UK as a whole. The breakdown of emissions from road transport demonstrates that measures can be targeted at all vehicle classes and that the effectiveness review should consider the impact of measures on both light and heavy duty vehicles.

Table 1 - Summary emissions data for Wales and UK

Metric	Wales	UK
Proportion of Emissions of NOx from Road Transport	28.5%	33.7%
Proportion of Emissions of NOx from Road Transport from Heavy Duty Vehicles (including buses)	18.3%	22.6%
Proportion of Emissions of NOx from Road Transport from Light Duty Vehicles (excluding cars)	31.8%	29.8%
Proportion of Emissions of NOx from Road Transport from Passenger Cars	49.5%	47.4%
Proportion of Emissions of NOx from Road Transport from Motorcycles/Mopeds	0.3%	0.3%

[1] UK Plan for tackling roadside nitrogen dioxide concentrations, 2017, Available at https://www.gov.uk/government/publications/air-quality-plan-for-nitrogen-dioxide-no2-in-uk-2017

[2] For the purpose of assessing compliance with the EU Ambient Air Quality Directive, Wales is divided into 4 zones, 2 urban agglomeration zones (Cardiff and Swansea) and 2 non-agglomeration zones (North Wales and South Wales).

[3] Available at https://uk-air.defra.gov.uk/library/no2ten/2017-zone-plan-documents. (Zone 26 Cardiff Urban Area Zone Plan; Swansea Urban Area Zone Plan; Zone 41 South Wales Zone Plan; Zone 42 North Wales Zone Plan)

[4] Air Quality Pollutant Inventories for England, Scotland, Wales and Northern Ireland: 1990 – 2015, report prepared for Department for Environment, Food and Rural Affairs; The Scottish Government; Welsh Government; Department of Agriculture, Environment and Rural Affairs for Northern Ireland. Available at http://naei.beis.gov.uk/reports/reports?report_id=895

1.2 APPROACH

1.2.1. In general, air quality benefits can be effected in two ways: through reductions in emissions at source and/or reductions in exposure to air quality. Potential measures can impact on either or both emissions and exposure reduction.

1.2.2. Emissions reductions can result from:

- *Avoiding emissions*, for example, by encouraging the use of sustainable travel, or providing information to effect behaviour change
- *Decreasing emissions*, for example, through congestion relief measures or the adoption of low emission vehicles

1.2.3. Exposure reductions can result from:

- *Displacement of emissions*, for example, through the use of variable diversions and traffic management measures
- *Concentration reduction at receptors*, for example, through installation of barriers between source and receptor

1.2.4. The effectiveness review has considered the potential measures under 7 Key Themes

Theme.	Example
Air Quality Technology	Use of technology/options to reduce the concentration of air pollutants once they have been released to air. Examples include filtration, surface coatings; barriers, canopies, tunnels, vegetation screening
Sustainable Transport	Measures designed to encourage sustainable transport. Examples include encouraging modal shift through improved bus/rail provision, parking improvements to facilitate car sharing, provision on eco-driving, ensuring planning decisions prioritise air quality mitigation measures, provision of charging points
Communications	Measures designed to provide information to public that encourages behaviour change. Examples include provision of real time air quality information, declaration of 'Air Quality Areas', and working with SatNav providers to incorporate air quality into route specification
Policy and Funding	Measures designed to reduce emissions. Examples include promotion of ultra low emission vehicles, increased vehicle emission testing, clean air zones, strengthened links to local air quality management
Network Demand and Capacity	Measures designed to avoid or reduce emissions through congestion relief, road closures, increased capacity. Examples include enforcing/reducing speed limits, HGV overtaking bans, flow management, junction closures or ramp metering
Traffic Management	Measures designed to avoid, reduce or divert emissions through traffic management services. Examples include Intelligent Traffic Management, improved traffic officer services, traffic lights
Network and Asset Management	Measures designed to avoid, reduce or divert emissions using infrastructure changes. Examples include route realignment, provision of cycle lanes, traffic smoothing using distance chevrons

1.2.5. Figure 1 shows the interactions between the aims of emission and exposure reduction, the mechanisms to achieve the aims and the Key Themes. It's readily apparent that there is significant overlap between the Themes and the potential for packages of one or more measures is high.

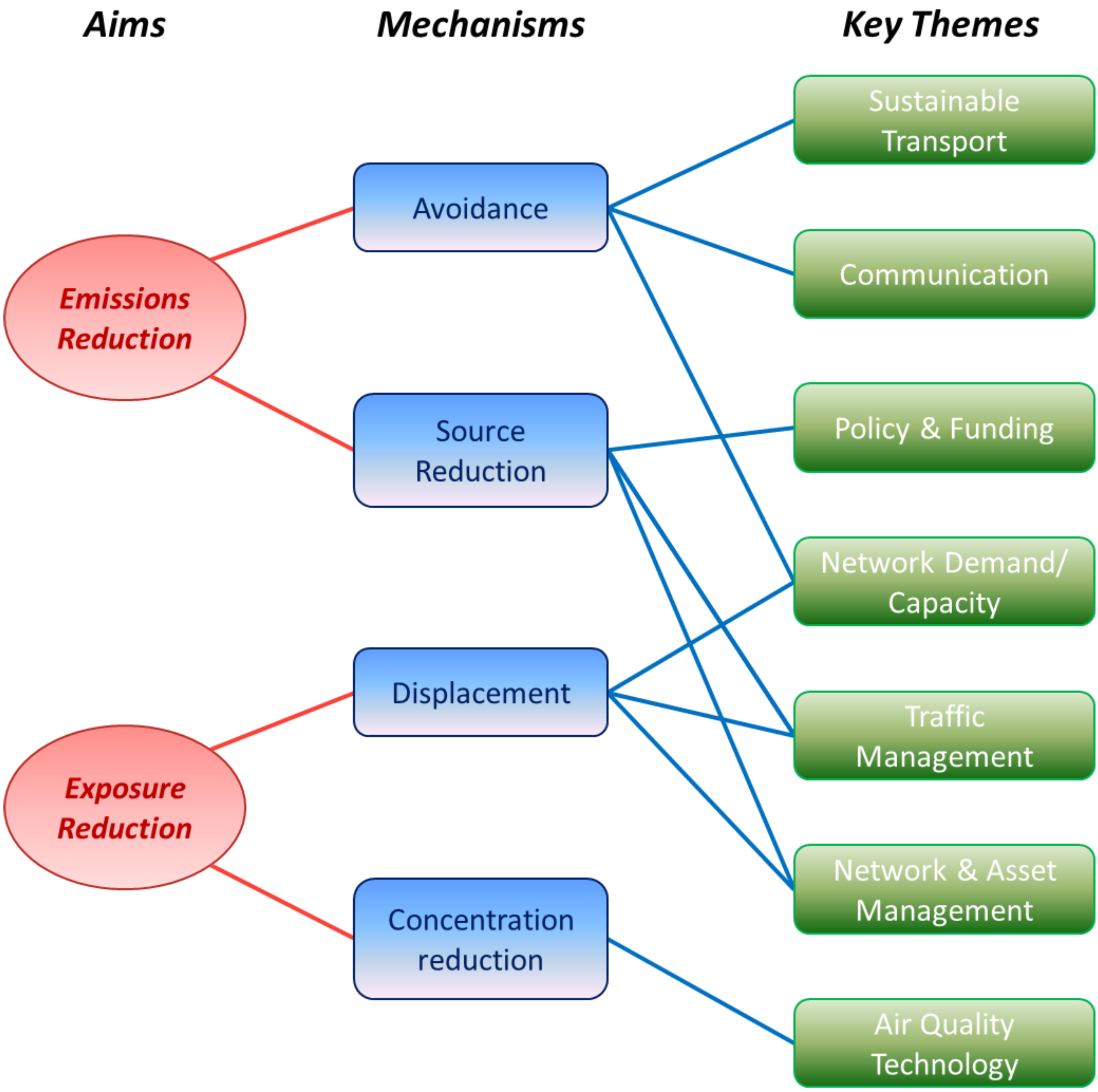

Figure 1 – Key themes under which measures were reviewed

1.3 SCOPE AND METHODOLOGY

Scope

1.3.1. The study was commissioned as a rapid review of potential measures and the availability of evidence to support the effectiveness of the measures. In particular, the study considered the availability of evidence for the application of measures to strategic networks and focussed on measures that could be implemented by Welsh Government using its powers as Highway or Traffic Authority for the strategic road network.

1.3.2. The review had a single primary objective:

To establish to what extent potential measures could assist in bringing forward reductions in NO_2 in the shortest possible time

1.3.3. Evidence of costs, economic impacts or other secondary criteria are not noted in this review, with the exception of consideration of un-intended consequences where those consequences could lead to deterioration in air quality elsewhere or where the measure could lead to notable inequalities in impact.

Methodology

1.3.4. The study has been based on a literature review of:-

- Published Scientific Articles – identified through on-line databases
- Grey Literature – identified through publicly available websites and holdings of the Project team

1.3.5. The on-line databases searched for published articles included Science Direct, PubMed, Deepdyve and Google Scholar.

1.3.6. Grey literature reports (literature produced outside of academic publishing) were identified through publicly available websites, the reference library of the Project team, and through the online report databases of relevant organisations (e.g. Defra, Environment Agency, GLA, TfL, SEPA, Transport Scotland, and Devolved Administrations).

1.3.7. Defra commissioned an evidence review on the effectiveness of transport measures in reducing nitrogen dioxide [Defra, 2016a]. This review has been taken as the starting point of this work. In order to supplement the evidence generated by the Defra Evidence Review Defra, the search was initially undertaken for 2016 onwards, with additional literature sources searched prior to 2016 on the basis of citations within relevant searches.

1.3.8. The review considered the evidence base for the effectiveness of measures in changing emissions, exposure of the public, traffic characteristics and travel behaviours.

1.3.9. During the review, it became apparent that there was relatively little field evidence available on the air quality impacts of measures for which the aims are more traditionally traffic rather than air quality related, i.e. measures designed to increase capacity, reduce congestion, ramp metering, diversions etc. For these measures (under the Key Themes of Traffic Management, Network Demand and Capacity, Network and Asset Management), the potential effectiveness of the measure was inferred for this report from the data available on the impact of the measure on traffic flows and speeds coupled with the data available on vehicle emissions as a function of speed (Defra's Emissions Factors Toolkit (EfT)[5]).

1.3.10. As such, measures are considered in the review under each of the Key Themes, although the volume of evidence within each Theme is variable.

1.3.11. Whilst it is acknowledged that there is uncertainty associated with the performance of certain vehicle classes in the EfT (diesel cars in particular), this does not place a significant constraint on the study. The analysis of the effectiveness of the measure is based on the overarching trends in emissions as vehicle speeds or volumes change. These are well established and largely independent of absolute emission levels.

1.3.12. Within the EfT, in general:

- for light duty vehicles, emissions of NOx are elevated at low speed (indicative of congested/stop-start flow conditions) and at high speed (indicative of high engine load), with optimised emissions in the speed range 50 – 80kph
- for heavy duty vehicles, emissions of NOx are highly elevated at very low speed (<20kph) and decline as speeds increase, with little change with speed above 70kph

[5] As reflected by the Emissions Factor Toolkit (EfT) provided by Defra and the Devolved Administrations to assist local authorities with their Local Air Quality Management duties. Available at https://laqm.defra.gov.uk/review-and-assessment/tools/emissions-factors-toolkit.html

1.3.13. The EfT incorporates the expected natural turnover of the fleet with the replacement of older more polluting vehicles with newer, clear vehicles. Frequent reference is made within this review to 'Euro' classes for vehicles. These classes denote the standards used for vehicle classification, with light duty vehicles denoted using arabic numerical 1 to 6, heavy duty vehicles denoted using roman numerals I to VI, and the standards becoming more stringent as the number increases. New vehicles coming onto the market must conform to the Euro 6/VI standards.

1.4 REPORT STRUCTURE

1.4.1. The remainder of the report is structured as follows:

- Section 2: Review of Defra's Recent Reports
- Section 3: Review of Low Emission Zones and Strategies across the UK
- Section 4: Review of Other Literature
- Section 5: Conclusions

2 EXISTING UK GOVERNMENT REPORTS ON NITROGEN DIOXIDE REDUCTION

2.1 UK PLAN FOR TACKLING ROADSIDE NITROGEN DIOXIDE CONCENTRATIONS – TECHNICAL REPORTS

2.1.1. In the development of the UK Plan for tackling roadside nitrogen dioxide concentrations (July 2017), Defra, Department for Transport and the Devolved Administrations (hereafter, collectively, referred to as Defra for conciseness) published two technical evidence reports

- the first in support of the Draft UK Air Quality Plan (May 2017[6]) and
- the second, substantially changed, in support of the final UK Air Quality Plan (July 2017[7]).

2.1.2. For the May 2017 Technical Report, Defra undertook a multi-criteria analysis of 49 potential measures to reduce NO_2, taking into account air quality impact, timing to implement, deliverability and five additional considerations looking at costs, societal benefits, greenhouse gas emissions, and strategic and economic aims. For the resulting short-list of feasible measures, Defra modelled the potential air quality impact in the earliest implementation year (Table 2).

Table 2 – Summary of impacts from the analysis of the shortlisted policy measures (May 2017 Technical Report, reproduced in July 2017 Technical Report Annex J)

Measure	WG Effectiveness Review Theme	Air quality impact	Timing to Impact
Clean Air Zones	Policy & Funding	8.6µg/m3 in 2020	1-3yrs
Speed Limits **Reduce motorway speed limits to 60mph where there is poor air quality**	Network Demand and Capacity	Up to 2.5µg/m3 in 2021	>3yrs
Retrofit **Retrofitting of buses, HGVs and black taxis between now and 2020**	Policy & Funding	0.09µg/m3 in 2019	1-3yrs
Influencing Driving Style **Training and telematics for 100,000 car and van drivers by 2020**	Sustainable Travel	0.012 µg/m3 in 2019	1-3yrs
Scrappage **National scheme promoting a transfer from older conventional cars and vans to electric**	Policy & Funding	0.008µg/m3 in 2020	1-3yrs
Ultra Low Emission Vehicles **Providing additional support to purchasers of electric vehicles**	Policy & Funding	0.008µg/m3 in 2017	<1yr
Vehicle Labelling **AQ emissions information on new car labels**	Communications	0.004µg/m3 in 2017	<1yr
Government Buying Standards **Priority for petrol cars over diesel**	Policy & Funding	0.0005µg/m3 in 2018	<1yr

2.1.3. The most effective measures, with potential air quality impacts more than an order of magnitude higher than all other measures, were the introduction of Clean Air Zones (CAZ) and reduction in speed limits on motorways.

[6] https://consult.defra.gov.uk/airquality/air-quality-plan-for-tackling-nitrogen-dioxide/supporting_documents/Technical%20Report%20%20Amended%209%20May%202017.pdf
[7] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/632916/air-quality-plan-technical-report.pdf

2.1.4. Importantly, in the July 2017 Report, Defra identified a number of areas of the UK that were considered suitable for CAZs (Annex F). These specifically excluded routes

- on the strategic road network controlled by Highways England and
- single roads and exceedances where the traffic is predominantly "through traffic" not immediately heading towards a city centre.

2.1.5. The Welsh strategic road network was not listed as a specific exclusion from CAZ consideration but, outside of the Cardiff urban area, falls under the second bullet point above i.e. the areas of exceedance are on limited stretches of road where the traffic is mainly "through traffic".

2.1.6. Annex H to the July 2017 Technical Report set out a summary of the potential effectiveness of measures to tackle exceedance in areas not suitable for CAZ[8].

2.1.7. Defra reported that evidence of the potential effectiveness of measures to tackle exceedances not suitable for a CAZ is subject to significant uncertainty and limited by the poor availability of robust quantifiable evidence of the effects on NO_2 concentrations. Furthermore, they identified that no single measure was likely to be applicable in all situations.

Traffic management (WG Effectiveness Review Themes: Network Demand and Capacity, Traffic Management

2.1.8. As reflected in Defra's EfT, vehicle testing typically finds that drive cycles with lower average speeds produce lower NOx emissions (unless speeds are reduced significantly by congestion). This is, however, subject to significant uncertainty and many confounding variables, including typical driving dynamics, the extent of acceleration, weather conditions, and others. Notwithstanding this, overall, there is reasonable cause to expect this measure to reduce emissions in some areas.

2.1.9. Where traffic is relatively free flowing, there is some empirical evidence to support this claim. Eight published studies that evaluated the impact of traffic management on air pollution (Baldasano, 2010; Olde Kalter, 2008; Stoelhorst, 2011; Keller, 2008; Bel, 2013; Bel et al, 2015; Keuken, 2010;) were reviewed. Taking into account the studies that estimated the overall reduction in NOx emissions, the average impact across these studies was a 10.9 per cent reduction.

Signage and rerouting (WG Effectiveness Review Themes: Traffic Management, Network Demand and Capacity)

2.1.10. Urban traffic re-routing, through dynamic signage, has been cautiously estimated as resulting in 10 percent of all vehicles responding to the diversion advice, as result of a study in Copenhagen and another in Amsterdam (Levecq).

2.1.11. The Copenhagen study implied that the number of travellers likely to take the optional route (at least 12 percent of the time) is likely to increase as the journey time shown between the original and optional route grew. In the Amsterdam study, display signs on the ring-road led to a drop of between 25 to 33 percent in congestion was observed, and between 8 to 10 percent of drivers responded to displayed information on normal conditions.

Changes to driver behaviour (WG Effectiveness Review Themes: Sustainable Travel)

2.1.12. Eco-driving improves fuel economy by as much as 15 per cent, though this can decline over time to an average of 4% in fuel savings as driver behaviour becomes less influenced by the training received (TNO, 2006). It has been inferred that NOx emissions are likely to decline with the application of eco-driver techniques as less fuel is used during a journey, but no quantitative evidence was identified as to the level of saving.

[8] Taken from Evidence review on effectiveness of transport measures in reducing nitrogen dioxide: Appendix 1 to project summary report for contract AQ0959 'Exploring and appraising proposed measures to tackle air quality', Defra, 2016

2.2 EVIDENCE REVIEW ON EFFECTIVENESS OF TRANSPORT MEASURES IN REDUCING NITROGEN DIOXIDE (DEFRA, 2016)

2.2.1. Defra commissioned a report on the effectiveness of measures to reduce NOx emissions in pursuit of compliance with EU limit values for NO_2. The results informed, in part, the measures identified within the UK Plan for non-CAZ areas.

2.2.2. The analysis of various abatement measures suggested that the most cost-effective measures in terms of delivering air quality benefits are those that specifically target air quality (as opposed to transport measures that have air quality benefits as secondary objectives). However, these measures were most effective when targeted at urban hot-spots and less effective if applied elsewhere. Schemes to target local NO_2 hot spots at, for example, road junctions, were unlikely to provide optimum environmental benefits.

2.2.3. In the more polluted areas of the UK, the measures identified as having the greatest potential to reduce NO_2 concentrations focussed on reducing the demand for use of diesel vehicles, particularly for passenger cars, and promoting new technology through the uptake of new vehicles.

2.2.4. However, the promotion of low emission vehicles is not always as effective as expected due to low uptake.

2.2.5. Traffic management and access control measures (low emission zones, parking management, temporary access restrictions etc.) can be very effective in reducing/removing sources of air pollution. They are however widely politically unpopular. Demand management measures to encourage a shift away from single person car use to sustainable transport modes can also be very cost effective but may take time to become effective due to reluctance to change habits and travelling attitudes. Information campaigns can address this, but their effectiveness may tail off over time. Schemes linking traffic management and air quality monitoring are currently implemented in Utrecht (realtime goods vehicle routing) and Leicester (pre-programmed traffic control to optimise air quality benefits).

2.2.6. Pricing mechanisms, through existing taxation systems, can be cost-effective means to increase sales of low NOx emissions cars. However, the review indicated that there were potential negative impacts on social equality with the measure. Schemes such as road tolls need to be designed with care to discourage traffic displacement to more populated and polluted areas. The evidence for the effectiveness of measures in urban areas is unclear.

2.2.7. The literature review reported that Low Emission Zones (LEZ) were an effective measure to improve air quality in towns and cities. However, field evidence for the effectiveness of LEZs across Europe is mixed. The successful implementation of a LEZ required a consistent set of design criteria, supplemented with complementary measures (vehicle retro-fitting, incentivisation schemes for cleaner vehicles, encouraging modal shift) and a communications plan. Evidence from Germany showed that a communications plan, explaining the rational for the LEZ and providing information on alternative travel models, is essential to the effective implementation of LEZs.

2.2.8. The review concluded that the full benefits of LEZs will only be realised once vehicle emissions in real driving conditions are aligned with test conditions.

2.2.9. LEZs could be actively enforced, for example using Automatic Number Plate Recognition (ANPR) to restrict or penalise access by the most polluting vehicles, or indirectly/passively enforced, using speed enforcement or traffic calming measures.

Gaps in the evidence base

2.2.10. The Defra report concluded, in common with many other studies, that quantitative evidence post-implementation of measures was lacking. Results were rarely presented with acknowledgement of the uncertainty of the result and interference from additional effects was not always taken into account, e.g. meteorological effects on pollution levels. Future impact evaluations using reliable data will be essential in order to justify implementation of cost-effective policies to reduce NO_2 concentrations from road transport.

2.2.11. Previous assessment reports had been based on superseded emission factors, and now would not represent the same impact if current emission factors were used. Few studies were observed to report results from before and after measures were implemented or to compare results between similar areas with measures and without measures.

2.2.12. Though the Defra review reported little available data over the development of a measure, from its announcement, initial implementation and then full implementation, there was good evidence on congestion charge schemes. This highlighted the need for complementary measures to maximise LEZ benefits.

2.2.13. Numerous LEZ feasibility studies have been undertaken in the UK but there are evidence gaps in the likely uptake with general assumptions being made. Early indications are that the Oxford LEZ has removed exceedances of the hourly mean NO_2 limit value.

2.2.14. Measures to reduce fuel costs are effective in driving fuel savings but NOx emissions reductions are not a direct output of fuel savings. Published evidence on the impact of fuel-efficient driving on NOx emissions is limited and there is a lack of certainty relating to the use of driver behaviour to abate or reduce NOx emissions

2.2.15. No substantial evidence was found in relation to changes to travel behaviours should an LEZ be implemented. In order to build a set of complementary measures, understanding travel behaviour in response to an LEZ would increase the probability of a set of complementary measures succeeding. However there was no evidence on the optimum combination of air quality improvement measures.

2.2.16. The Defra Review report called for further research and analysis on air quality impacts pre- and post-implementation of measures to strengthen the evidence and understanding of air quality improvement measures.

2.3 IMPLICATIONS FOR STRATEGIC ROAD NETWORK IN WALES

2.3.1. The key measure set out in the UK Plan for reducing NO_2 pollution in urban areas (CAZ) is not identified as an appropriate measure for reducing exceedances of the NO_2 limit values on the strategic road network in Wales. Moreover, the Defra effectiveness review identified that the most cost-effective measures for reducing NO_2 emissions were aimed at reducing demand for the use of polluting diesel vehicles but such measures were considered less effective when applied outside of urban centres.

2.3.2. The evidence base, particularly from studies in the Netherlands, indicates that ***indirectly enforced Low Emission Zones***, based on **speed enforcement** or management could provide significant emissions reductions where traffic is currently free flowing. Evidence for the efficacy of LEZ based on restricting vehicle access according to emissions standards is mixed although evidence from Germany indicates that LEZs, applied to all vehicle classes and accompanied by **communications plans** explaining their purpose and providing transport information, are the most effective.

2.3.3. Congested roads outside of major urban areas (or on their periphery e.g. the M4 around Newport) with significant “through traffic” were not specifically considered in the Defra effectiveness review, and the most effective congestion relief measures were aimed at urban areas (restriction of vehicles in central area, road pricing, improved frequency of public transport, parking management). The common factor amongst these measures is, however, the management of congestion through reductions in demand. As such, some measures could be implemented on the strategic network, including provision of ***diversion information*** (with around 10% of drivers responding to the information in urban areas), restriction of local trips on the network (through ***junction closures***) and increased uptake of sustainable transport models (***behaviour change***).

2.3.4. Road tolls/user pricing were potentially effective in reducing demand on the strategic network but could result in drivers using alternative routes with lower capacity, greater congestion and air quality disbenefits through greater roadside exposure (since the alternative routes are frequently through residential areas).

2.3.5. Other pricing and policy measures, such as scrappage schemes, incentivising the uptake of low emission vehicles through taxation, may be effective in reducing NOx emissions but are not measures that could be implemented by Welsh Government using its powers as Highway or Traffic Authority for the strategic road network and fall outside of the remit of this review.

3 REVIEW OF LOW EMISSION ZONES AND SELECTED LOW EMISSION STRATEGIES AND TRANSPORT PLANS IN THE UK

3.1 OVERVIEW

3.1.1. Low Emission Zones have been implemented in 5 UK cities. London, Oxford, Brighton, Norwich and Nottingham. With the exception of London, the LEZ are focussed on emissions from buses.

3.1.2. In addition, many areas across the UK have adopted low emission strategies (LES). The following reports on LES and related transport plans were reviewed for evidence of source apportionment and emission reduction potential.

- City of York Low Emission Strategy, 2012
- West Midlands Low Emission Bus Delivery Plan, July 2016
- West Yorkshire Low Emissions Strategy 2016 to 2021, December 2016
- West Midlands Transport Authority 2026 Delivery Plan for Transport
- Greater Manchester Air Quality Action Plan, 2016–2021
- Greater Manchester Low Emission Strategy
- Birmingham City Council City Blue Print for Low Carbon Fuel Infrastructure
- Technical Work Package 7, Monitoring Strategy, Birmingham Connected Mobility Action Plan Technical Study Group November 2014
- Technical Work Package 2, Public Transport. Birmingham Connected Mobility Action Plan Technical Study Group November 2014
- Air Quality Plan for tackling roadside nitrogen dioxide concentrations in West Midlands area (Defra July 2017).
- Air Quality Information for Public Health Professionals – City of London (GLA, 2012)
- An evaluation of the estimated impacts on vehicle emissions of a 20mph speed restriction in central London (Imperial College London, 2013).

3.2 UK LOW EMISSION ZONES

London Low Emission Zone

3.2.1. London currently has the most ambitious LEZs in the UK. The LEZ was introduced in February 2008 and modified in 2012. It required that larger diesel vehicles meet low emissions standards, namely Euro 3 for larger vans and minibuses; Euro IV for HGVs and buses. Further measures have recently come into force or are planned for implementation in the coming years. The T-charge (toxicity charge), introduced in October 2017, extended the LEZ standards to smaller vehicles and requires that light duty vehicles (cars, vans and minibuses) meet Euro 4 standards and heavy duty vehicles / buses and coaches meet Euro IV standards. The T-Charge will be replaced by the Ultra Low Emission Zone (ULEZ) in April 2019. The ULEZ is expected to reduce NOx emissions by around 50% in central London. In addition, there are 12 Low Emission Bus Zones across London which will put the greenest buses on the capital's most polluted routes and pure diesel double deck buses will be phased out from 2018. The measures are expected to reduce emissions by 84% in the bus zones. From the first of January 2018, all new taxis licensed needed to be zero emission capable. The T-Charge has not been in place for sufficient time to assess its impact, but the original LEZ did not significantly improve air quality within London in its first 3 years of operation (Wood *et al*, 2015; Holman, Harrison and Querol, 2015). In particular, the LEZ did not result in the expected reduction in emissions of NOx which may be due to the failure of diesel cars (which were unaffected by the zone restrictions) to reproduce test data under real-world driving conditions.

Oxford Low Emission Zone

3.2.2. The zone was established in 2014 to manage emissions from the city's bus fleet. The LEZ ensures that all buses entering the city meet a minimum of Euro V standards. Pollution levels in the city have been declining since 2012 (Oxford City Council, 2016). No evidence has been made available to assess whether the reduction in pollution levels can be attributed to the LEZ, either wholly or in part. Oxford is currently considering an option for a zero emission zone in the city centre to accelerate pollution reduction.

Brighton Low Emission Zone

3.2.3. The zone was established in 2015. As in Oxford, it relates to buses alone and requires that buses entering the city centre meet Euro V standards or better (targeting the highest mileage buses in the first instance). Taxis are not covered by the LEZ but are observing no-engine idling policies. Brighton and Hove City Council report that concentrations in the LEZ are improving at a faster rate than elsewhere within their district (Brighton and Hove City Council, 2017) but further monitoring is required to provide more robust evidence.

Norwich Low Emission Zone

3.2.4. The zone was established in 2009. It was aimed at regulating emissions from buses together with additional softer measures including an engine switch off Traffic Regulation Order, and the offer of free 'Eco-driving' training sessions to bus operators. Grants were provided to help bus operators upgrade their fleet, initially to Euro IV standard but Euro V under review together with emissions from taxis. The impact of the zone is unclear with Norwich City Council reporting in 2015 that "in recent years NO_2 [has] been increasing but probably would have been worse without LEZ" (Brighton and Hove City Council, 2015)

Nottingham

3.2.5. The zone requires that public buses entering the city meet Euro 3 standards are a minimum. No information was identified to assess the impact of the LEZ.

3.3 LOW EMISSION STRATEGIES

3.3.1. Brief summaries of key findings from each report are provided below:

City of York Low Emission Strategy

3.3.2. The LES was introduced in 2012 in response to an increase in NO_2 concentrations in the city between 2004 and 2010. Measures included encouraging the uptake of alternative fuels and low emission vehicles across the HGV, bus and taxi fleets including purchase of new electric vehicles and retrofitting existing vehicles, and installation of electric vehicle charging points. As of April 2017, approximately 13% of the taxi fleet had been converted to Euro 5_ hybrid or electric types. In addition, the Local Transport Plan (LTP3) and the i-Travel York programme included measures to encourage modal shift to sustainable transport (walking, cycling and public transport). The LES has been successful in increasing the use of electric vehicles and ambient NO_2 concentrations have decreased since 2012. However it has not yet been possible to attribute the decrease to the LES. Further measures being considered focus on continuing to increase zero emission vehicles.

West Yorkshire Low Emissions Strategy:

3.3.3. The LES is based on reducing emissions from transport through encouraging the uptake of new technologies with low or ultra-low emissions and implementation of a Clean Air Zone in Leeds (requiring Euro 6/VI taxis, vans, buses and lorries). A 195% increase in electric vehicle ownership was registered across West Yorkshire in 2015. In Bradford, bus emissions were identified as responsible for 40% of the emission on the inner ring road with Euro V buses considered to be have higher emissions of NOx than Euro IV buses due to their catalysts being ineffective at low speeds. The LES incorporates an Electric Vehicle Strategy, primarily aimed at provision of charging points, and a Bus Strategy requiring new buses to meet the latest emission standards (Euro VI) whilst moving towards near to zero emissions buses.

Birmingham Connected Work Package 2

3.3.4. The Birmingham Connected work package was aimed at developing a strategy for integrated public transport within the city based on mass transit. The long term goal is to develop a rail-based Metro but in the short to medium term the network will be delivered predominantly by Bus Rapid Transit (known as Sprint).

3.3.5. Birmingham City Centre is covered by an existing Statutory Quality Partnership Scheme (SQPS), negotiated with bus operators and including arrangements to improve connectivity across the city which promotes the use of public transport. However, to meet implementation timescales, the SQPS compromised on bus emissions and other vehicle standards based planned and realistic fleet replacement strategies of the bus operators. No stretching targets for the improvement of services and the fleet were made, and the opportunity for emissions improvements at the time was effectively lost but the emission standards will be raised to ensure that all vehicle meet Euro VI standards post 2022 when the current SQPS expires.

3.3.6. It is envisaged that the proposed Sprint network will take a phased approach to moving towards zero emission status, with Diesel Electric Hybrid buses proposed to be introduced between 2015 – 2019, Plug-In Hybrid Electric Diesel Propulsion between 2020-2024 and Battery Propulsion post 2025. Therefore emission will be gradually reduced, though not significantly until after the full introduction of Hybrid Electric Diesel Propulsion buses.

3.3.7. The Birmingham Connected network is intended to operate as a comprehensive, integrated sustainable transport system and will incorporate consistent ticketing and information supply. Promotion of Green Travel Districts in the Public Transport plan includes several Urban Transport Interchanges which are sustainable transport interchanges located on-street to facilitate intermodality. These are likely to have a positive impact on modal shift.

Birmingham Connected Technical Work Package 7, Monitoring Strategy

3.3.8. Air Quality Monitoring data is to be included with the monitoring strategy for part of the success of the Birmingham Connected Mobility Action Plan.

Birmingham City Council City Blue Print for Low Carbon Fuel Infrastructure

3.3.9. There are currently 107 Electric 200 electric vehicle charge points across the City and 8 LPG vehicle gas stations. The Blue Print aims to encourage the uptake of low carbon vehicles and facilitate the provision of the necessary infrastructure to support electric, hydrogen and natural gas vehicles.

West Midlands Low Emission Bus Delivery Plan:

3.3.10. There are currently 2,300 buses operating in the West Midlands. Of these approximately 200 buses will replaced each year. Currently 52 buses are low emission hybrids and almost half the fleet are older, Euro III buses. As old buses are replaced, NOx emissions from the total bus fleet are expected to fall by 64% by 2020 through natural turnover and the use of Euro VI buses. The delivery plan aims to bring about further emissions reductions through the adoption of Low Emission Buses (natural gas / electric / hydrogen fuelled), amounting to between 35% and 54% of NOx emissions in 2035.

West Midlands Transport Authority 2026 Delivery Plan

3.3.11. The West Midlands Strategic Transport Plan, 'Movement for Growth', aims to improve the transport system to support economic growth and regeneration, underpin new development and to improve air quality, the environment and social inclusion.

3.3.12. The main themes relating to air quality focus on improving emissions and concentrations of pollutants by encouraging transport modal shift from using private cars to more sustainable methods of transport such as cycling and walking, and mass transit. The proposed Birmingham Clean Air Zone falls within the remit of the Delivery Plan and there are also some low emission strategies, including the Low Emission Bus Delivery Plan, in place so that the vehicle fleet can be transformed into using greener fuels and technology.

Greater Manchester Low Emission Strategy

3.3.13. The Strategy takes a long-term approach to carbon emissions and air quality, aiming to reduce emissions from transport and encourage sustainable travel including public transport, cycling and walking.

3.3.14. Transport is by far the biggest local source of NOx emissions, with goods vehicles and buses making a disproportionate contribution to NOx emissions. The proposed measures for reducing emissions fall into the themes of:

- Changing travel behaviour – encourage sustainable transport through improved provision of an integrated transport and ticketing system and investing in infrastructure for active travel models
- Managing emissions – improving network efficiency through traffic management, including giving buses priority
- Greening vehicle fleets - reducing pollution from vehicles through the promotion of low-emission vehicles through the provision of charging infrastructure and specification of emissions standards for buses and car club vehicles
- Awareness raising – including cleaner vehicles campaigns and information provision through the GreatAir Manchester website.

3.3.15. The proposed SMART motorway scheme between junction 8 of the M66 and Junction 20 of the M62, was recognised as having a potentially significant negative impact on air quality, and cannot proceed unless emissions can be reduced.

3.3.16. The Strategy concluded that, due to the sheer traffic volume, emissions from passengers cars must be tackled in the long term but that the greatest short term benefits would be felt by focussing on heavy goods vehicles and on buses on key routes.

Air Quality Information for Public Health Professionals – City of London

3.3.17. The City of London Authority has recognised the contribution that the high proportions of HGVs (between 18 - 21%) and buses (between 30 – 56%) make to emissions on roads in areas of very poor air quality in central London.

Estimated impacts on vehicle emissions of a 20mph speed restriction in central London -Imperial College London

3.3.18. Microsimulation modelling estimated NOx emissions from petrol vehicles were increased when switching speed restrictions from to 30 mph to 20mph, and decreased for diesel vehicles.

3.4 IMPLICATIONS FOR STRATEGIC ROAD NETWORK IN WALES

3.4.1. With the exception of the London LEZ, the existing LEZs in the UK all focus on emissions from buses. The evidence for their efficacy in improving air quality is not robust. Moreover, the applicability of such measures to the strategic road network is limited due to the far lower contribution that buses and coaches make to total emissions on the strategic road network in Wales in comparison to city centres. Typically, buses and coaches amount to a less than 1% of vehicles on the strategic network in areas of poor air quality[9].

3.4.2. Existing LESs across the UK focus on facilitating the move to low-emission vehicles through the provision of infrastructure to support electric and other alternative fuel vehicles and on encouraging modal shift/active travel.

3.4.3. In relation to low emission vehicles, there is, as for LEZs, a focus on buses and taxis. This is understandable given the greater control that local authorities have on bus and taxi fleets than on private vehicles (through licensing arrangements) but it is of limited applicability to the strategic road network.

3.4.4. Encouraging modal shift has a potential role to play in ***reducing demand to travel*** on the strategic road network, particularly where there is a clear focus to the traveller, e.g. travel into major urban centres (Cardiff and Swansea) and/or along the M4 corridor. Without this focus, it is difficult to envisage any measures to encourage modal shift being cost-effective or capable of providing significant emissions savings unless multiple destinations are offered.

3.4.5. The promotion of active travel models, walking and cycling, is unlikely to provide significant air quality benefits on the strategic road network since the likely journeys are relatively long in comparison to typical urban journeys.

3.4.6. Traffic management measures, designed to facilitate congestion relief and smoother driving conditions, played little or no role in the LESs and the evidence for their impact was mixed. Similarly, LESs were not concerned with free flowing roads where speed limits could play a role in emissions management.

[9] From review of DfT transport statistics, available from https://www.dft.gov.uk/traffic-counts/, for count points on roads showing exceedance of limit values in Defra's PCM modelling.

4 REVIEW OF ADDITIONAL LITERATURE

4.1 SEARCH CRITERIA

4.1.1. The search criteria and terms used to identify and select relevant articles from on-line databases were structured in terms of the following criteria:

- Evidence surrounding vehicle NOx emission reduction
- Detectable evidence of a measures impact
- Limitations / opportunity of a Measures implementation

4.1.2. Of the articles initially selected using relevant search terms (Nitrogen Dioxide Reduction, "Emissions Reduction", Vehicle Emissions") relatively few articles were observed to achieve above criteria, and as such, the evidence base was extended to include:

- Traffic changes resulting from Measure implementation (where AQ direct evidence is unavailable)

4.2 REVIEW OF RECENT EVIDENCE

4.2.1. A summary of the literature review, covering evidence not included in the Defra studies, is provided below as a function of the effectiveness review themes.

Table 3 Literature review summary

Theme	Evidence	Outcome	Reference
Air Quality Technology			
	NOx removal efficiency of up to 50% was achieved using Titanium Oxide (TiO_2) sprayed on set concrete, rather than incorporation TiO2 in binding agents for wet concrete.	NO_2 abatement treatment can be applied to multiple surface types.	Kim, 2014
	A titanium oxide (TiO_2) penetration method is a preferable and more effective alternative to the existing TiO_2 concrete catalytic reduction of NO_2.	Slight changes in abatement measures can greatly improve reduction efficiency.	Kim, 2017
	Modelling of removal and replenishment of NOx in idealised street canyon resulted in maximum reduction of 0.7% of NOx. Actual effects likely to be smaller; field trials equivocal	Photocatalytic surfaces can reduce concentrations but unlikely to be significant	Air Quality Expert Group, 2016
	NO_2 concentrations decreased with increased density of canopy of street vegetation. In vegetated areas reductions in NO_2 were observed at elevations of 1.5 and 5m, though not at 10m.	Distinct reductions in NO_2 are achieved through use of street vegetation, though its impacts at height are limited.	Desyana, 2017
	Deposition is one of the principal mechanisms by which vegetation may reduce the concentration of air pollutants. Location of vegetation is a key factor in how this affects air pollution concentrations. Vegetation protruding above building roof height increases pollutant concentrations, whereas vegetation below building roof height with a high deposition velocity may mitigate air quality problems in streets and reduce air pollutant concentrations.	Solid vegetative barriers mitigate pollutant concentrations through vertical mixing, whereas highly porous vegetative barriers reduce winds speeds and can lead to higher pollution concentrations	Ghasemian 2017
	Large trees reduce mixing and potentially increase pollution; low vegetation close to sources can improve air quality by increasing deposition.	Design and choice of urban vegetation to reduce air pollution is crucial	Janihall 2015

	Two viable design options for reducing air pollutants are wide vegetation barrier with high Leaf Area Density and vegetation-solid barrier combinations.	Impacts of vegetation on reducing air pollutant concentration are particle size dependant.	Tong 2016
	Particles of different size classes have different physical behaviour along open and vegetated areas. Smaller particles have higher residence times, and larger particles have shorter residence times. The presence of trees can increase air pollutant concentrations, with aerodynamics influencing PM2.5 concentrations more than surface area available for deposition. All of this was considered to be contingent on wind direction.	Downwind recirculation zones must be taken into account when considering designing landscapes intended to mitigate air pollution.	Zheming, T 2015
	Concentrations of aerosolized particulates were lower at sites close to large areas of greenspace.	Street vegetation can adsorb air pollutants, improving air quality.	Irga, 2015
	Street canyon concentrations of NO_2 can be reduced by up to 40% by using vegetation to increase deposition.	Significant reduction in ambient concentrations of NO_2 can be brought about by street vegetation	Pugh, 2012
	Field trial showed reductions in particulate matter concentrations of up to 50% downwind of noise barrier; on-road levels did not increase in front of barrier; Reductions extend 300m from the road.	Solid barriers can reduce exposure to pollution.	Baldauf, 2016
	Conditioned active diesel particulate filters have been observed to achieve a 96% NO_2 reduction.	Large emissions reductions are achievable with small abatement measures.	Ibrahim, 2016
	Diesel vehicles in urban areas are responsible for 90% of the NOx emissions.	Targeting diesel emissions will greatly assist compliance.	Harrison, 2017
	There is significant potential for NO_2 reductions if regulatory standards for light duty diesel vehicles were to be met under real-world operating conditions.	Targeting regulatory emissions compliance by LDDVs will promote air quality compliance.	Schneidemesser, 2017
	Improving emissions standards of Brazilian cities' buses fleets to meet upcoming standard, P-8, would reduce annual NOx bus fleet emission by 40%, as opposed to a 26% reduction from realistic uptake rates of electric buses with only the P-7 emissions standard.	Where infrastructure limits the uptake of new technology (battery buses), it is better to use available technology (Euro VI) buses to reduce emissions in the short/medium term	Miller, 2017
	Road-side emissions monitoring in Germany confirmed real-world traffic fleet that the emissions comprehensively exceed the legal limits. Compounding uncertainty in the predictions of ambient air compliance to legal NO2 limits are of the concentrations in urban air.	Predicted impacts of NO_2 concentrations in ambient air as an outcome of emissions reduction measures can be unreliable.	Peitzmeier, 2017

Sustainable Travel			
	Changes in behaviour were tracked following provision of new infrastructure in UK. Loss of employment, high education, being male and part of the ethnic majority were found to be significantly and positively associated with modal shift	Construction of walking and cycling routes promotes modal shift but infrastructure alone may not be enough to promote active travel	Song, 2017
	Traffic conditions and the type of the day (regular, weekend, or holiday) affect vehicle emissions (as VSP) by up to 30.1% and 56.7%, respectively. Bad weather conditions were found to induce 26.7% higher VSP values whereas daylight was found to induce 8.7% lower VSP values.	There are secondary and tertiary effects on vehicle emissions, including driver induced and traffic conditions.	Pellecuer, 2016;
	Cycle routes for commuters should avoid high motorised traffic routes to minimise exposure to air pollution.	Health risks act as a disincentive to uptaking of active travel options.	Cole-Hunter, 2012
	Tehran study claimed an improvement in ambient air after the installation of a rapid bus transit system.	Successful low emission public transport options can bring about improved air quality.	Beigi, 2017
Communications			
	As a result of reporting of poor air quality, 12.0% of individuals, especially those with a respiratory condition (25.1%) and other adults (14.2%), reported changing activities.	Positive behaviour change led to an improvement in air quality, reduction in NO_2 emissions.	Wells, 2012
	Information on poor air quality was observed to positively influence behaviour change. Participants who suffered from lung disease were more prone to act and avoid car driving during poor periods of poor air quality.	Information supply led to positive behaviour change with respect to air quality emissions.	Skov, 1991
	Use of personal air pollution sensors generated greater motivation to behaviour change among study participants than just being informed of poor air quality through conventional means of communications.	Information supply led to positive behaviour change with respect to air quality emissions.	Oltra, 2017
	Lack of behaviour change response has been linked to poor supply of public information.	Poor information supply results in low uptake of positive behaviour change	Semenza, 2008
	Air quality alerts were observed to succeed for private gain (exposure reduction) and be less successful for public gain (emission reduction).	Poor information supply results in low uptake of positive behaviour change.	Noonan, 2011
Policy and Funding			
	NOx reduction was observed in some kerosene / biodiesel fuel blends.	Use of Biodiesel / kerosene blends could provide a marginal reduction in NOx emissions of road vehicles.	Kumar, 2016
	Addition of selected additives to bio-diesel was observed to influence a reduction on NOx emissions.	Use of Biodiesel / kerosene blends could provide a marginal reduction in NOx emissions of road vehicles.	Madiwale, 2017

	NOx emissions for all biodiesel blends decreased at lower loads and increased at higher loads.	Use of Biodiesel / kerosene blends could provide a marginal reduction in NOx emissions of road vehicles.	Churkunti, 2016
	A reduction of 11.9% in NOx was observed with certain Biodiesel and diesel blends.	Use of Biodiesel / kerosene blends could provide a marginal reduction in NOx emissions of road vehicles.	Yilmaz, 2017
	New clean Euro VI diesel buses were simulated to lower total annual road transport NOx emissions by 6.5%.	Significant NOx emissions reduction has been predicted by upgrading fleets to Euro VI.	Tate, 2017
	Vehicle Emission Testing for annual MoT shows a failure rate on emissions of less than 2%	-	DfT, 2015
Network Demand and Capacity			
	Congestion tax in central Stockholm was recorded as reducing ambient pollution levels by between 5 to 10 percent.	Vehicle restriction measures directly led to improvements air quality.	Simeonova, 2017
	Milan introduced a combined LEZ (diesel vehicles must be Euro 3, petrol vehicles Euro 0) and congestion charging zone (termed Ecopass, then Area C). Traffic decreased by 30% and PM10 concentrations by 4%. Decreases in NO_2 concentrations were not reported.	Vehicle restriction and emissions management led to improvements in air quality but no information provided in relation to NO_2	
	Air pollution in LEZs were observed to decrease emissions by approximately nine percent in urban traffic centres, while pollution is unchanged in non-traffic areas. Vehicle owners were observed as being incentivised to adopt cleaner vehicles the closer they are to an LEZ.	Vehicle targeted emissions measures have a direct effect on reducing traffic emissions. Vehicle owners adapt to driving restrictions.	Wolff, 2014
	Speed management led to between 5-30% reduction in NOx, with largest impact on motorways with high % of HGVs.	Speed management measures directly led to improvements air quality.	Keuken, 2010
	Saturday driving restrictions failed to reduce air pollution in Mexico City.	A population may not consistently respond to an adaptation of a vehicle driving restriction.	Davis, 2017
	Vehicle restrictions can have different responses rates across various income groups. Some households are able to respond rapidly to policy changes.	Vehicle restrictions may not be taken up due to lack of resource amongst lower income groups.	Gallego, 2013; Viard, 2015
	Beijing monitoring records have recorded air pollution falls 21% during one-day-per-week restrictions. 24-hour average concentration of NO_2 is 12% higher on days when less common vehicle plates are restricted	Focussed and restrained vehicle restrictions can achieve significant emissions reductions, though can fail if too focussed or selective.	Zhong, 2017.
	HGV overtaking bans have greatest benefits on sections of roads with uphill gradients and high proportion (>25%) of HGVs	On uphill sections, decrease in speeds of HGV and increase for LDV; downhill, increase in speeds for all classes. Impact is insignificant if demand is low	TRL Ltd, 2010

	Ramp metering can reduce occurrences of flow breakdown if applied to suitable sites	To be effective in reducing flow breakdown, the speed on the main carriageway should fall to below 50kph for at least 1hr per day, demand on the slip road needs to be relatively high	Highways England Interim Advice Note,
	M4 J41 Westbound On-slip Peak Time Trial Closure improved journey time reliability on the mainline (westbound) with no effect eastbound and a reduction in flow downstream of the junction. Upstream flow increases were identified and queue lengths increased on some parts of the diversion route	Junction closure could result in AQ benefits, but they need to be well planned to ensure that the unintended consequences don't outweigh the benefits	Welsh Government, 2015
Network and Asset Management			
	Field study used to evaluate distance between vehicles and vehicle speeds, before and after installation of distance chevrons	Distance chevrons result in a reduction in tailgating but a slight reduction in mean speed.	Greibe, 2010

5 CONCLUSIONS

5.1.1. The rapid evidence review has identified measures that could be applied on the Strategic Road Network (SRN) in Wales to reduce concentrations of NO_2 at the roadside.

5.1.2. However, the majority of the evidence base relates to the management of air quality in an urban setting and is not immediately applicable to the SRN. Moreover, it is suggested that measures are less effective when targeted at localised NO_2 hotspots (or sections of road in exceedance of limit values) rather than broad city-wide areas. Hotspots are considered inappropriate for CAZ mitigation measures.

5.1.3. The review indicates that for the SRN, measures aimed at the whole fleet, or targeted at light duty diesel vehicles (passenger cars and vans) could be effective, particularly when combined with information campaigns. There is strong evidence to suggest that the public comply with restrictions more readily if the reason for the restriction is well understood.

5.1.4. Within the Air Quality Technology Theme, the most effective measures are potentially those involving the installation of either solid and/or vegetation barriers. The evidence base includes field trials demonstrating the benefits of barriers. Some, but not all studies, show an increase in pollution levels on the road itself, inside the barrier, but exposure durations on the road will be considerably less than at residential properties.

5.1.5. In relation to the use of Sustainable Transport and Policy and Funding, the promotion of low emission vehicles can have a beneficial impact on air quality, but only if the uptake rates are substantial. On the SRN, with significant levels of through traffic, uptake of low emission vehicles is likely to be low without significant incentives (scrappage schemes) that are outside of the remit of Network Management and the scope of this study.

5.1.6. Low Emission Zones, based on speed control rather than vehicle type control, could provide significant benefits on high speed sections of the SRN.

5.1.7. Demand management on the SRN through, for example, variable diversions and/or junction closures has the potential to reduce impacts on the SRN but may result in adverse unintended consequences where drivers chose to re-route through other air quality management areas or areas of relatively poor air quality. As an alternative, the evidence indicates that it is possible to encourage modal shift from private, single user car trips through improved provision of infrastructure for active travel, public transport and/or car sharing. Demand management through road pricing or other punitive measures could potentially increase social inequalities.

5.1.8. Some schemes with dynamic diversions based on air quality criteria are in operation in Europe. Such measures could be implemented on the SRN but measures that affect the whole fleet throughout the whole day are preferred.

5.1.9. Overall, there is, however, a paucity of information on the quantitative impacts of air quality mitigation measures and, in particular, on the impacts of groups of measures. As such, it is recommended that where measures are implemented on the network Welsh Government ensures that an appropriate NO_2 monitoring regime is also implemented pre, during and, if relevant, post measure.

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