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Best practices in managing emissions from road transport

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Executive summary

The Triangular Cooperation Air Quality Improvement Project is being led by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and supported by Ricardo Energy & Environment. The Triangular Cooperation includes India as the beneficiary country, Mexico as the south offer and Germany as the traditional offer. Ricardo Energy & Environment is supporting the project by sharing examples of best practice in air quality management with the cities of Cuttack and Bhubaneswar in India

This Best Practice Review identifies examples of good practice across 45 transport-related air quality measures in the following categories:

- Direct emission control
- Fuel switching
- New technologies
- Mode shift
- Transport and urban planning
- Air quality monitoring and data
- Communication and engagement

The measures within each group have been evaluated to assist in identifying the measures which are likely to be the most useful for Cuttack and Bhubaneswar.

Direct emission control measures include measures such as driving bans and low emission zones, emissions standards for private, public transport and commercial vehicles, street cleaning, and road or path maintenance, among others. These measures aim to directly remove transport emissions before they are emitted. Direct emission control measures, in general, provide an impact on air quality on a relatively short timescale, and were not found to be reliant on other measures in order for them to work. The costs are often high. Key examples of best practice include emissions standard, anti-idling and smoky vehicle enforcement in Singapore, the bus low emission zone and upcoming Zero Emission Zone in Oxford (UK), and a ‘climate friendly’ asphalt in Copenhagen (Denmark).

The fuel switching measures category includes measures such as vehicle upgrades, with a focus on buses and taxis, and incentives for cleaner vehicles. This category has a focus on cleaner technologies, but not the newest technologies (i.e. electric vehicles) because it is important to consider that cities or individuals may not be in a position to afford an electric vehicle or vehicle fleet. Cleaner vehicles of other types, like higher Euro standards, hybrid vehicles or retrofitting options also reduce pollutant emissions. Fuel switching measures were found to not rely on other measure in order for them to work effectively, and were scored relatively highly for innovation. Although the costs are not as high as for electric vehicles, the costs are still significant. The impact on air quality was found to be quite variable between the measures included. Examples of best practice can be found in German cities such as Reutlingen that have made the most of a grant from the European Commission to retrofit buses, and Cambridge (UK)’s use of taxi licensing conditions and the Clean Vehicle Retrofit Accreditation Scheme.

New technologies include electric vehicles, again with a focus on buses and taxis, electric charging infrastructure, compressed natural gas and active dust binding. This category includes the more recent and innovative developments to reduce emissions from transport. New technologies are innovative, but electric vehicle measures are very reliant on other measures – either the electric vehicles themselves, the infrastructure required, or the promotion and uptake. This reliance can make the timescale for implementation be quite long. The costs are also very high. Dortmund, Reutlingen, and other German cities have made use of another European Commission grant to purchase electric buses, while Hamburg (also in Germany) is trialling an electric autonomous bus. Other examples of best practice are demonstrated in the use of active dust binding, combined with enhanced street cleaning to reduce particulate matter emissions in the Nordic countries (Denmark, Finland, Norway, and Sweden).

Mode shift measures focus significantly on public transport measures such as improving the infrastructure and service quality and providing discounted and intermodal tariff offers. It also includes cycling measures including cycle networks, priority bicycle routes or junctions, cycling infrastructure and bike rental. These measures change a person's mode of transport from a private vehicle to another mode of transport - be that public transport, cycling, walking, or car sharing. Mode shift measures are

again very reliant on other measures in order to have an impact on air quality. However, they can be quite innovative and provide a range of co-benefits, more so than any other category. Zurich in Switzerland provides one of the best examples of a constantly expanding and improving public transport system, while Mannheim and Berlin in Germany demonstrate extensive cycle networks with clear prioritisation for cyclists in the city centres.

Transport and urban planning measures include actions such as dynamic traffic management and truck routeing, parking controls or guidance, and speed limits. These measures, in general, decrease transport emissions by smoothing the flow of traffic. This works because it reduces the amount of stop-start traffic, which releases more emissions than travelling smoothly at a continuous speed. The measures target both moving traffic, and stationary traffic. Transport and urban planning measures in general have a low reliance on other air quality measures, and provide quite a few co-benefits. As there is such a mix of measures, they vary between being costly or cheap, innovative or not, and the prospective timescales are also variable. Key examples of best practice in this category include Reutlingen and Berlin in Germany, which both have a form of dynamic traffic management that is well-established, and in Oxford there are a range of parking control and guidance measures.

Air quality monitoring and data measures include the collection of air quality data and air quality forecasting, as well as the collection of mobility or transport data. Collection of air quality monitoring data is vital to understand the air quality situation in a city, including which pollutants are the biggest problem, where the pollution hotspots in the city are, and who is exposed to pollution. The data can also be used to help raise awareness with the public, and to measure the impact of other actions to reduce pollutant emissions from transport. Air quality monitoring and data measures have a low impact on air quality on their own, as they do not directly impact emissions of pollutants from transport. However, they benefit from low costs and are quick to implement. The UK's Automatic Urban and Rural Network (AURN) is a good example of a country-wide air quality monitoring network, which feeds into the UK's air quality forecasting system 'UK AIR', presented by the Department for the Environment, Food, and Rural Affairs (DEFRA).

Communication and engagement measures include promotional actions, for example to promote park & ride or bike & ride services, electric vehicles, cycling, or alternative mobility options in general. It also covers educational measures such as air quality displays, dynamic passenger information systems and informing the public about rules or regulations relating to air quality measures like clean air zone charges. The aim of these measures is broadly to inform the public about air pollution and what opportunities they have to improve air quality. As with air quality monitoring and data measures, communication and engagement measures have a low impact on air quality, as they do not directly impact emissions of pollutants from transport. However, they tend to be low-cost and quick to implement. Examples of best practice in communication and engagement include promotional events such as EUROPEANMOBILITYWEEK, Mannheim (Germany)'s "200th Birthday of the Bicycle" and Jakarta (Indonesia)'s monthly 'Car Free Day'. Informative websites such as for Oxford's upcoming Zero Emission Zone provide useful information for residents so they can adhere to new rules in the city, be prepared, and avoid fines.

The findings from the review have enabled us to identify specific individuals/partners in cities in Germany and the UK to interview, to provide more in-depth understanding of key success factors for effective interventions, and those that may be recommended for implementation as part of the Triangular Cooperation Project. These findings will be discussed at the Best Practice Exchange and Reporting Session later in the year.

Hamburg is the 'gold standard' in terms of air quality measures and associated infrastructure. Hamburg has a well-established EV charging infrastructure, including public transport as well as private vehicles. The most recent "Master Plan for Designing More Sustainable and Emission-Free Mobility in Hamburg" contains further measures to expand electromobility, such as continued expansion of the electric bus fleet and procurement regulations for other modes of transport. Of particular interest is also the bilateral mobility partnerships that have been agreed with companies including Volkswagen, BMW, and Daimler, as well as Hamburg's role as host of the Intelligent Transport Systems World Congress in October 2021.

Berlin has a wide range of measures that contribute to air quality improvements and demonstrate best practice in their respective fields. Berlin's state-of-the-art traffic control centre

(Verkehrsregelungszentrale, VKRZ) is responsible for monitoring and manually activating traffic light systems at 2,000 intersections in Berlin, for operating Variable Message Sign systems on motorways, for monitoring the traffic situation on over 1,500 km of roads, and for transmitting traffic information from the regional reporting office – these actions all help to keep the flow of traffic in the capital smooth, and reduce transport emissions. Another area of interest is cycling; Berlin has improved the cycling infrastructure through large increases in funding, and demonstrated the importance of cycling by increasing cyclists' representation in the Senate. There are an increasing number of protected bicycle lanes that separate cyclists from automobile traffic – these green lanes help improve safety with their visibility and can be quickly installed. Another interesting measure is the use of e-cargo bikes for 'last mile' delivery, which was trialled during a temporary project (KoMoDo); approximately 120 e-cargo bikes are now available to rent under the 'fLotte kommunal' scheme run by the German Bicycle Club Berlin e.V. (ADFC Berlin).

Reutlingen in Germany was selected as one of five model cities that the German Federal Environment Agency would support with additional funding to the "Immediate Clean Air Program". There are a number of interesting measures outlined in the Green City Plan for Reutlingen, some of which have been in place for a number of years and others which are proposed for the near future. The city has an established dynamic traffic management system and parking guidance system, both of which have further improvements planned. The 'truck route concept' combines banning trucks from certain routes with support for HGV owners/drivers and is an innovative solution to one of the more polluting vehicle types. Reutlingen also has plans to expand the EV infrastructure to support an increased number of EV buses, private vehicles and an electric carshare fleet. Additional measures to promote public transport such as provision of Wi-Fi, driver training and even automated vehicles may be of interest to the Indian cities.

Mannheim in Germany was also selected as one of five model cities that the German Federal Environment Agency would support with additional funding. The city has a significant focus on improving the share of cycling. A successful cycling strategy has been in place since 2010, achieving a 5% increase in cycling within three years, and further increases were targeted for 2020. Mannheim is the birthplace of the "running machine" (predecessor to the bicycle) and celebrated the 200th birthday of the bicycle in 2017 – a great example of using events to promote alternative forms of transport. Mannheim also presents an interesting method statement including the use of 'central traffic hubs as mobility stations' where various types of public transport are linked, as well as cycle paths, footpaths, and potentially other forms of mobility.

Oxford provides an example of high-standard air quality practices in the UK. The city has developed a range of measures as part of their Low Emission Strategy to support air quality improvements, notably in the areas of freight traffic management, expansion of zero emission vehicle uptake and developing public transport. Oxford City Council has installed electric charging points in and around the city to encourage use of electric vehicles. Another key measure for Oxford is the current pilot Zero Emission Zone.

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Glossary

Abbreviation	Definition
ADB	Asian Development Bank
AETCs	Auto Emission Testing Centres
ANPR	Automatic Number Plate Recognition
AQAP	Air Quality Action Plan
AQI	Air Quality Index
AQMA	Air Quality Management Area
ASR	Annual Status Report
AURN	Automatic Urban and Rural Network
BAFA	Federal Office for Economics and Export Control (Germany)
BSIV/ BSVI	Bharat Stage IV/VI
BWVI	Hamburg's Ministry for Economics, Transport, and Innovation (Germany)
B&R	Bike & Ride
CAAP	Clean Air Action Plan
CAAQMS	Continuous Ambient Air Quality Monitoring Stations
CaCl2	Calcium chloride
CAMS	Continuous Air Monitoring Stations
CAZ	Clean Air Zone
CCAC	Climate and Clean Air Coalition
CMA	Calcium magnesium acetate
CNG	Compressed Natural Gas
CO	Carbon monoxide
CO_2	Carbon dioxide
COE	Certificate of Entitlement
CPZs	Controlled Parking Zones
CVES	Commercial Vehicle Emissions Scheme
DAQI	Daily Air Quality Index
DfT	Department for Transport (UK)
DOC	Diesel oxidation catalyst
DoE	Department of the Environment

Abbreviation	Definition
DPF	Diesel particulate filter
DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V. (German Aerospace Center)
DEFRA	Department for the Environment, Food and Rural Affairs (UK)
EEA	European Environmental Agency
EEV	Enhanced Environmentally friendly Vehicles
EC	European Commission
EDMC	East Delhi Municipal Corporation (India)
ETS	Early Turnover Scheme
EU	European Union
EV	Electric vehicle
FEDRO	Federal Roads Office (Switzerland)
FOEN	Federal Office of the Environment (Switzerland)
GCP	Greater Cambridgeshire Partnership
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GLOSA	Green Light Optimised Speed Advisory
GoWB	Government of West Bengal (India)
GPVs	Goods-cum-Passenger Vehicles
HaLm	Hamburg air measurement network (Hamburg, Germany)
HC	Hydrocarbons
HEAT	Hamburg Electric Autonomous Transportation (Hamburg, Germany)
HGV	Heavy goods vehicle
HSRP	High Security Registration Plates
INES	Intelligent adaptive traffic control system, used in Reutlingen (Germany)
ITS	Intelligent Transport Systems
KMA	Kolkata Metropolitan Area (India)
KMC	Kolkata Municipal Corporation (India)
KMDA	Kolkata Metropolitan Development Authority (India)
LED	Light-emission diode
LES	Low Emission Strategy
LEV	Low Emission Vehicle
LEVC	London Electric Vehicle Company

Abbreviation	Definition
LEZ	Low Emission Zone
LGV	Light goods vehicle
LPG	Liquified petroleum gas
LSBG	Department of Roads, Bridges and Water (Hamburg)
LSVA	Performance-related heavy vehicle charge (Switzerland)
LuQx	Daily air quality index / Luftqualitätsindex (Baden-Württemberg, Germany)
MaaS	Mobility as a Service
MER	Monitoring, Evaluation and Reporting
$MgCl_2$	Magnesium chloride
MoEn	Ministry of Energy (Lahore, Pakistan)
MoPNG	Union Ministry for Petroleum and Natural Gas (India)
MoRTH	Union Ministry of Road Transport and Highways (India)
NAAQS	National Ambient Air Quality Standard
NABEL	National Air Pollution Monitoring Network (Switzerland)
NAPCC	National Action Plan on Climate Change (India)
NCAP	National Clean Air Programme
NEA	National Environment Agency (Singapore)
NEERI	National Environmental Engineering Research Institute (India)
NEQS	National Environmental Quality Standards (Pakistan)
NGOs	Non-Government Organisations
NH_3	Ammonia
NIC	National Informatics Centre (Kolkata, India)
NO	Nitrogen monoxide
NO_2	Nitrogen dioxide
NOx	Nitrogen oxides
O_3	Ozone
OLEV	Office for Low Emission Vehicles (UK)
OTS	Oxford Transport Strategy
Pak-EPA	Pakistan Environmental Protection Agency
Pb	Lead
PEPC	Pakistan Environmental Protection Council
PHV	Private Hire Vehicle

Abbreviation	Definition
PLS	Parking guidance system (Germany)
PM	Particulate matter
$PM_{2.5}$	Particulate matter 2.5 micrometres or less in diameter
PM_{10}	Particulate matter 10 micrometres or less in diameter
PQP	Prevailing Quota Premium
PUC	Pollution Under Control Certificate system
P&R	Park & Ride
QA/QC Unit	Quality Assurance and Control Unit
QBP	Quality Bus Partnership
RFID	Radio Frequency Identification Card, for paying for electric vehicle charging
RST	Route Selection Tool
RTA	Regional Transport Authority (Kolkata, India)
SAE	Society for Automotive Engineers (Hamburg, Germany)
SASS	System Activated Strategy Selection
SCADA	Supervisory Control And Data Acquisition
SCOOT	Split Cycle Offset Optimisation Technique
SCR	Selective catalytic reduction
SrV	System of Representative Transport (Germany)
STA	State Transport Authority (Kolkata, India)
SO_2	Sulphur dioxide
SO_X	Sulphur oxides
SPM	Suspended particulate matter
SPCB	State Pollution Control Board (India)
TfC	Travel for Cambridgeshire (UK)
TfL	Transport for London (UK)
TTG	Time-To-Green (Hamburg, Germany)
UK	United Kingdom
ULEV	Ultra-low emission vehicle
VES	Vehicle Emission Scheme
VKRZ	Verkehrsregelungszentrale / Traffic Control Centre (Berlin, Germany)
VMS	Variable Message Signs
VOCs	Volatile organic compounds

Abbreviation	Definition
VTS	Ordinance on the technical requirements for road vehicles (Zurich, Switzerland)
WBPCB	West Bengal Pollution Control Board (India)
WBTC	West Bengal Transport Corporation (India)
WHO	World Health Organisation
WPL	Workplace Parking Levy
WRAT	Walking route audit tool
ZEZ	Zero Emission Zone
ZML	León Metropolitan Area

1 Introduction

1.1 Project overview

The Triangular Cooperation Air Quality Improvement Project is being led by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and supported by Ricardo Energy & Environment. The Triangular Cooperation includes India as the beneficiary country, Mexico as the south offer and Germany as the traditional offer. Ricardo Energy & Environment is supporting the project by sharing examples of best practice in air quality management with the cities of Cuttack and Bhubaneswar in India, developing guidelines and recommendations for strengthening the cities' Clean Air Action Plans (CAAPs) and providing technical solutions for two identified measures for the improvement of emissions from transport sources. Throughout the project, experiences will be shared between officials from cities in Europe, Mexico, and India; these shared experiences will aid in identifying technical solutions for air quality management in Cuttack & Bhubaneswar.

Capacities will be strengthened for the development of strategies, programs, and action plans to combat air pollution, with viable technical and financial solutions and exchange of knowledge and experience to make the public policies operational. The three fields of action for the project are:

- Knowledge Exchange – Development of technical capabilities for improving air quality through facilitating knowledge exchange.
- Technical Support – Planning and implementation of clean air measures through technical support.
- Capacity building – Capacity building for replication in the Indian cities.

The overarching aim of the project is to facilitate collaboration between cities in India, Mexico, and Germany/Europe on effective air quality management practices, with a focus on road transport emissions. The project will be delivered in three packages:

- Package A will establish the needs of the Indian and Mexican cities, and gather evidence of effective air quality management from cities in Germany, as well as the UK and Asia.
- Package B will provide detailed recommendations on how to improve air quality management in the Indian cities, and suggest technical solutions.
- Package C will review the progress of the implementation of the recommended project.

1.2 Aims of best practice review

The International Best Practice Review is one of the key deliverables from Package A. The aim of the report is to review examples of effective urban air quality management in Germany and throughout the EU, focusing in particular on road traffic emissions.

The findings from the review have enabled the identification of specific individuals/partners in cities in Germany and the UK to interview, to provide more in-depth understanding of key success factors for effective interventions. At the end of each section, the measures within that group have been evaluated, taking into account the general information about the measure, the impacts and effectiveness of the best practice case studies, and consideration of the requirements of the Indian cities. The results of the evaluation will be helpful in providing guidance as to which measures are likely to be the most useful for the Indian cities of Cuttack and Bhubaneswar, and those that may be recommended for implementation as part of the Triangular Cooperation Project. These findings will be discussed at the Best Practice Exchange and Reporting Session.

This Best Practice Report will feed into Package B, which aims to provide detailed recommendations on how to improve air quality management in the Indian cities, and suggest technical solutions. This report provides a short summary of the air quality issues facing the Indian and Mexican cities. A more detailed review of the CAAPs in each city will be conducted under Package B, including the scope of measures, the robustness of the evidence base and the nature of implementation planning. By considering the requirements of the Indian cities, as well as the applicability of the best practice examples to Cuttack and Bhubaneswar, this report will provide a solid foundation from which to suggest specific technical solutions for implementation.

2 Transport emissions and air quality

Emissions to air resulting from road traffic arise come from various sources, including exhaust emissions, contributions from tyre friction and resuspended road dust. The pollutants emitted include a mix of particulate matter (PM) and gaseous pollutants (nitrogen oxides (NOx, the sum of nitrogen monoxide (NO) and nitrogen dioxide NO_2)), carbon monoxide (CO) and volatile organic compounds (VOCs)).[1] Most emissions from road transport are from fuel combustion (exhaust emissions), however, non-exhaust emissions are also significant, contributing to primary PM (from tyre- and brake-wear, and road abrasion) emissions.

According to the World Health Organisation (WHO), all of the aforementioned pollutants pose a risk to human health, with PM representing the greatest potential threat.[2] Levels of pollutant concentrations vary between cities as well as over short distances, so some groups of people are much more exposed than others.[3] Some people are more vulnerable to the impacts of air pollution, including pregnant women, those with cardiovascular and/or respiratory disease, children, people aged 65 and older, and those who are situated closer to main roads.[4] According to a review of evidence by the WHO in 2005, the various health implications of exposure to traffic-related air pollution include: mortality, nonallergic respiratory morbidity, allergic illness and symptoms (such as asthma), cardiovascular morbidity, cancer, pregnancy issues, birth outcomes and male fertility implications. Some occupational groups, such as professional drivers and railway workers, show increased incidence of and mortality from lung cancer, particularly when exposed for long periods of time.[5]

Air pollution, specifically $PM_{2.5}$ exposure, is responsible for around 400,000 premature deaths per year in the EEA-39 (excluding Turkey), whilst a recent study estimates up to 2.5 million premature deaths a year in India alone.[6] The most common reasons for premature deaths attributed to air pollution are heart disease and strokes, followed by lung diseases and lung cancer, with new evidence showing associations with new-onset type 2 diabetes in adults, obesity, Alzheimer's disease, and dementia.[7]

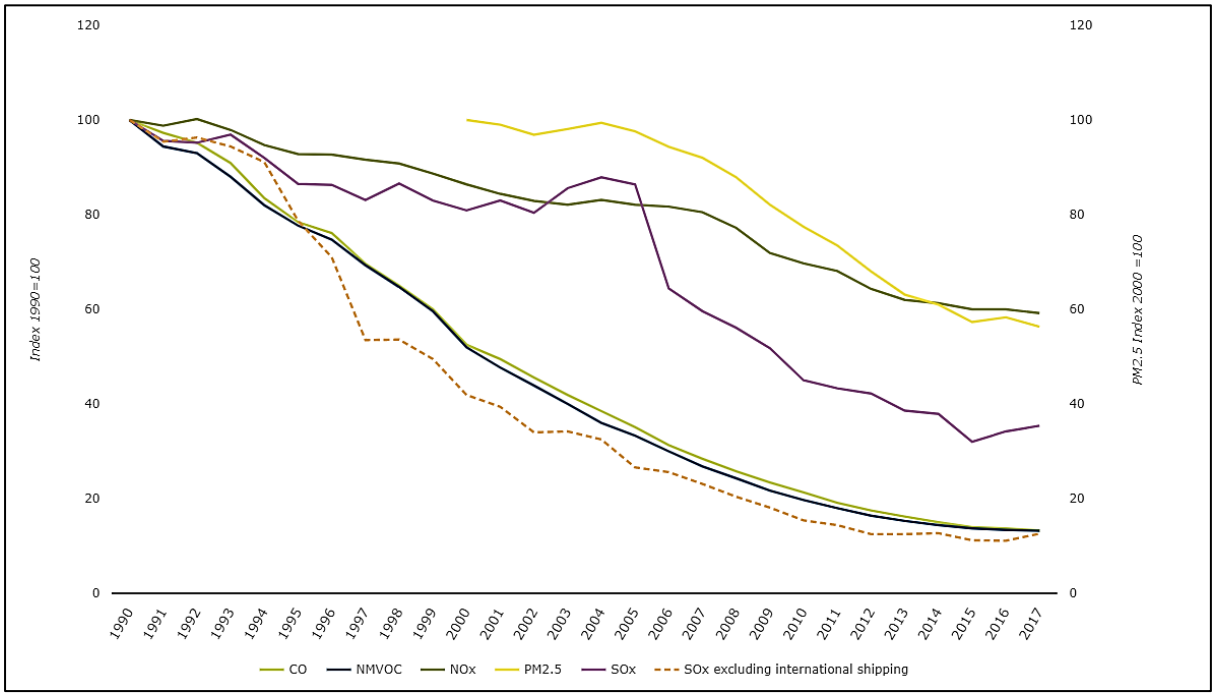
Air pollution also poses a significant risk to sensitive ecosystems, for instance excessive quantities of NOx and ammonia (NH_3) emissions impact aquatic ecosystems by causing eutrophication, while ozone (O_3) can reduce plant growth rates, impacting crop and forest yields. Pollutants from transport emissions can also damage materials, buildings, and artworks through corrosion, soiling and weathering, impacting the cultural and economic value of urban areas. As well as air quality concerns, emissions from transport contribute to greenhouse gases (GHGs) in the atmosphere, such as methane and carbon dioxide. Therefore, policies to improve air quality may contribute to efforts to reduce GHGs and minimise global climate change. All of the impacts mentioned above have economic implications, with market and non-market costs such as health expenditure, crop yield losses and increased mortality and morbidity.[8]

In Europe, emissions from transport are generally falling, with significantly reduced emissions from NOx (40% between 1990-2017), $PM_{2.5}$ and PM_{10} (44% and 35% respectively between 2000-2019).[9] Trends in emissions of air pollutants from transport in Europe can be seen in Figure 1. Road transport emissions

[1] Health effects of transport-related air pollution, 2005, p.54, available online at: https://www.euro.who.int/__data/assets/pdf_file/0006/74715/E86650.pdf
[2] Health effects of transport-related air pollution, 2005, available online at: https://www.euro.who.int/__data/assets/pdf_file/0006/74715/E86650.pdf
[3] Health effects of transport-related air pollution, 2005, p.85, available online at: https://www.euro.who.int/__data/assets/pdf_file/0006/74715/E86650.pdf
[4] Health matters: air pollution, 2018, available online at: https://www.gov.uk/government/publications/health-matters-air-pollution/health-matters-air-pollution#how-air-pollution-harms-health
[5] Health effects of transport-related air pollution, 2005, p.125, available online at: https://www.euro.who.int/__data/assets/pdf_file/0006/74715/E86650.pdf
[6] Vohra et al (2021) Global mortality from outdoor fine particle pollution generated by fossil fuel combustion: Results from GEOS-Chem, available online at: https://www.sciencedirect.com/science/article/abs/pii/S0013935121000487
[7] Air quality in Europe – 2020 report, 2020, p.10 available online at: https://www.eea.europa.eu//publications/air-quality-in-europe-2020-report
[8] Air quality in Europe – 2020 report, 2020, p.12 available online at: https://www.eea.europa.eu//publications/air-quality-in-europe-2020-report
[9] Emissions of air pollutants from transport, 2019, available online at: https://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-air-pollutants-8/transport-emissions-of-air-pollutants-8

accounted for 28.12% of NOx, 7.69% of PM_{10} and 9.89% of $PM_{2.5}$ total emissions in Europe in 2019.[10] Across the EU, emissions from all modes of transport have decreased since 1990, with policy interventions to deal with transport emissions increasing over recent years. This includes actions such as the development of local and regional air quality management plans which often involve congestion charges or low emission zones to combat air pollution.[11] Policy-driven technological improvements, fleet renewal and improvements in fuel quality have all been key steps towards the improvements seen in European air quality since the 1990s.[12] Progressively stricter emissions and fuel quality standards have led to significant reductions in emissions, while Directive 2008/50/EC sets limit values for EU Member States regarding the atmospheric concentrations of key pollutants, including NO_2, airborne PM (PM_{10} and $PM_{2.5}$), lead, CO and ozone.[13] The European Commission's recent 2018 strategy highlights the need to switch to low-carbon and zero-emission vehicles, emphasising the importance of electrification and efficiency improvements in the transport fleet.[14] The European Commission is also enforcing air quality standards in EU countries, for instance by referring France, Germany, and the United Kingdom to the Court of Justice of the EU for failing to respect agreed air quality limit values for NO_2, as well as Hungary, Italy and Romania regarding persistently high levels of PM_{10}.[15]

Figure 1: Trends in emissions of air pollutants from transport in Europe[16]



In India, there are over 100 'non-attainment' cities which have been found to violate the National Ambient Air Quality Standards (NAAQS), including 94 cities that have exceeded PM_{10} levels consecutively for five years, five cities for NO_2 and 16 cities for $PM_{2.5}$.[17] There are various ongoing initiatives to combat transport emissions, such as the National Clean Air Programme (NCAP).[18] The

[10] Contribution of the transport sector to total emissions of the main air pollutants, 2019, available online at: https://www.eea.europa.eu/data-and-maps/daviz/contribution-of-the-transport-sector-6#tab-chart_4
[11] Emissions of air pollutants from transport, 2019, available online at: https://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-air-pollutants-8/transport-emissions-of-air-pollutants-8
[12] Health effects of transport-related air pollution, 2005, P.55, available online at: https://www.euro.who.int/__data/assets/pdf_file/0006/74715/E86650.pdf
[13] Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe, 2008, available online at: https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:32008L0050
[14] A clean planet for all: A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, 2018, section 3, available online at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0773
[15] Air quality: Commission takes action to protect citizens from air pollution, (2018), available online at: https://ec.europa.eu/commission/presscorner/detail/en/IP_18_3450
[16] Emissions of air pollutants from transport, 2019, available online at: https://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-air-pollutants-8/transport-emissions-of-air-pollutants-8
[17] P.16 National Clean Air Programme, India, Ministry of Environment, Forest & Climate Change
[18] National Clean Air Programme, Ministry of Environment, Forest & Climate Change, Government of India, 2019.

NCAP creates a national-level strategy for reducing air pollution in India based on the context of policy interventions, integrating policies and programmes such as the National Action Plan on Climate Change (NAPCC)[19] with other government initiatives. Using a multi-sectoral and collaborative approach, the NCAP has a national level target to reduce $PM_{2.5}$ and PM_{10} by 20-30% by 2024, based on 2019 levels.[20] The programme includes mitigation actions such as stringent enforcement of monitoring and inspection, city-specific air quality management plans for the non-attainment cities, developing the air quality monitoring network, a review of emission standards, and improving public awareness and education. According to the Climate and Clean Air Coalition (CCAC), key next steps for reducing emissions from transport in Asia and the Pacific include the promotion of electric vehicles, improved public transport, strengthened emissions standards, dust control and improved vehicle inspection and maintenance.[21]

In Mexico, most progress to date has been made through air quality management programmes such as ProAire, which is based on scientific, technical, social and political considerations.[22] In 2018, heavy-duty vehicle emission standards were updated to allow Euro 4 equivalent until June 30 2019, Euro 5 until December 2020 and allowing Euro 6 indefinitely.[23] Mexican regulations state that all cities with more than 500,000 inhabitants, or above a certain industrial and motor vehicle load, should monitor the concentration of emissions and keep periodic update reports. However, there are many that still don't comply. Air quality standards are exceeded in various cities in the country. For example, in 2014, the regulated limits for PM_{10} (24 hours and/or annual), was exceeded in Ciudad Juárez, Monterrey, Toluca, Celaya, Torreón and Ciudad Victoria, among others.[24] On the other hand, in Mexico City, various measures have been implemented to improve air quality. For instance, reinforced vehicle inspection and maintenance programmes, implementation of catalytic converters in cars and an air quality forecasting system has been in place since 2017 to alert the public to high pollution events 24 hours in advance.[25] Mexico City's actions on air pollution mean that between 1990 and 2015, 3.2 to 3.4 years were added to the average life expectancy of citizens, saving an estimated 22,500 – 28,000 lives.[26]

[19] India's National Action Plan on Climate Change, 2009, available online at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2822162/#:~:text=The%20action%20plan%20outlines%20a,and%20climate%20change%2Drelated%20objectives.&text=National%20Water%20Mission%3A%20The%20NAPCC,a%20result%20of%20climate%20change.
[20] P.22 National Clean Air Programme, India, Ministry of Environment, Forest & Climate Change
[21] Air Pollution in Asia and the Pacific, 2019, available online at: https://www.ccacoalition.org/en/content/air-pollution-measures-asia-and-pacific
[22] Program to improve air quality in Mexico city – PROAIRE, 2021, available online at: https://img.climateinteractive.org/wp-content/uploads/2018/01/Proaire.pdf
[23] MEXICO: HEAVY-DUTY: EMISSIONS, 2018, available online at: https://www.transportpolicy.net/standard/mexico-heavy-duty-emissions/?title=mexico:_heavy-duty:_emissions
[24] National air quality strategy, 2017, p.21, available online at: https://www.gob.mx/cms/uploads/attachment/file/195809/Estrategia_Nacional_Calidad_del_Aire.pdf
[25] Mexico's mega city advances the fight for cleaner air, 2018, available online at: https://www.ccacoalition.org/en/news/mexicos-mega-city-advances-fight-cleaner-air
[26] Mexico, 2021, available online at: https://www.ccacoalition.org/en/partners/mexico

3 Project cities

A summary of the project cities in the beneficiary country, India, as well as the south offer country, Mexico, is provided below. Our understanding of the current air quality situation and the key issues in the cities is outlined following a high-level review of their CAAPs and the national clean air plan in each case.

3.1 India

3.1.1 Bhubaneswar, India

The city of Bhubaneswar lies within the state of Odisha, in the east of India. It is one of the six non-attainment cities in the state; in particular the concentrations of PM are an issue, with the most recent monitoring data indicating an exceedance of the annual National Ambient Air Quality Standard (NAAQS) for PM_{10} (60 μg/m^3).[27] The annual NAAQS for $PM_{2.5}$ (40 μg/m^3) is being met in Bhubaneswar (when considering the three-year annual average 2015 – 2017 presented in the CAAP),[28] however, as in many other Asian countries, both PM standards are less stringent than those set in the EU, or the guidelines published by the WHO. NO_2 concentrations are less of an issue in the Indian cities than in Europe, with the NAAQS for annual mean concentrations (40 μg/m^3, the same as the EU) being met in both Bhubaneswar and Cuttack. Air quality monitoring is currently carried out at six manual stations in the city that measure PM_{10}, $PM_{2.5}$, SO_2, NOx, NH_3, O_3 and lead (Pb) concentrations.[29] There are plans to expand the monitoring network.

There is currently no source apportionment study for Bhubaneswar, although a detailed source apportionment and source inventory study is proposed in the CAAP. The emissions inventory presented in the CAAP shows that 28% of NOx emissions, 14% of PM_{10} emissions and 27% of $PM_{2.5}$ emissions come from transport.[30] Vehicles and road dust are identified as major sources of pollution in Bhubaneswar. According to the CAAP, all the non-attainment cities in Odisha are experiencing rapid increases in the number of motor vehicles registered each year; Bhubaneswar has the highest vehicle stock and the greatest number of private cars. Use of diesel cars is a particular issue in Bhubaneswar and auto-rickshaws also predominantly run on diesel. Compared to the other non-attainment cities in the state, Bhubaneswar has a relatively large provision of public transport (although still only 5.6%). City bus operation commenced in 2009 between Bhubaneswar-Puri-Cuttack-Khurda with nine routes, which increased to 23 routes by 2015. Due to lack of ridership, some routes were terminated and there are currently 17 routes operational. There has been a significant reduction in bus ridership since 2014; the current estimate is just over 23,000 daily passengers (down from 42,000 in 2012 – 2013). Strategies are needed to improve public transport ridership.

Odisha does not currently have a state-wide comprehensive electric vehicle (EV) policy, however, policy measures for EVs are being implemented in Bhubaneswar according to the CAAP. Under the Smart City Programme, Bhubaneswar developed an E-mobility Plan in December 2017. The key features of the plan are deployment of 148 e-buses, 500 e-rickshaws, 100 EV sedans and 1,000 e-cycles by 2021. Regarding EV infrastructure, 522 slow chargers and 85 fast chargers are to be installed and there is a target of 20% trips by EVs by 2021, increasing to 30% by 2030. There is a provision to reserve a minimum of 30% of parking spaces for EVs, with charging facilities. Use of electric sedans for municipal and regulatory agencies (Bhubaneswar Municipal Corporation, Bhubaneswar Development Authority, etc.) has been provided for. Detailed route planning and rationalization for e-buses, e-rickshaws and e-cycles has been completed.

[27] Graph 1, Comprehensive Action Plan for Clean Air for Non-Attainment Cities of Odisha, Air Quality Monitoring Committee, Government of Odisha – Bhubaneswar, 2018.
[28] Graph 2, Comprehensive Action Plan for Clean Air for Non-Attainment Cities of Odisha, Air Quality Monitoring Committee, Government of Odisha – Bhubaneswar, 2018.
[29] Table 1A, Comprehensive Action Plan for Clean Air for Non-Attainment Cities of Odisha, Air Quality Monitoring Committee, Government of Odisha – Bhubaneswar, 2018.
[30] Graph 4, Comprehensive Action Plan for Clean Air for Non-Attainment Cities of Odisha, Air Quality Monitoring Committee, Government of Odisha – Bhubaneswar, 2018.

3.1.2 Cuttack, India

Cuttack also lies within the state of Odisha and shares many of the same air quality challenges as Bhubaneswar. The city has three manual monitoring stations, measuring concentrations of PM_{10}, $PM_{2.5}$, SO_2 and NOx.[31] The annual NAAQS for PM_{10} (60 $\mu g/m^3$) is being exceeded in Cuttack, although the reported value is not as high as for Bhubaneswar.[32] The reported three year annual mean for $PM_{2.5}$ is equal to the NAAQS (40 $\mu g/m^3$), a worse situation than in Bhubaneswar.[33]

As with Bhubaneswar, there is currently no source apportionment study for Cuttack, but one has been proposed in the CAAP. There is no emissions inventory available in the CAAP, but vehicles and road dust are identified as major sources of pollution. In Cuttack there is rapid increase in the registration of new motor vehicles, and in particular a spike in registration of two-wheelers, which dominate the fleet in all cities in Odisha. The provision of public transport in Cuttack is reported to be 5.3%, however, the CAAP also states that none of the non-attainment cities except Bhubaneswar possess any form of formal public transport system within the city limits. A historic city, Cuttack has very narrow roads that cannot support large vehicles such as buses. There is also no space to widen the roads for public transport or cycle lanes, as is being done in Bhubaneswar. This is perhaps the biggest difference between the two Indian cities, and Cuttack will require innovative solutions to work around the challenge.

The CAAP considers control of vehicular pollution at two levels: reduction in tailpipe emissions and reduction in total vehicle miles travelled in cities. To reduce tailpipe emissions, the state of Odisha implemented the Bharat Stage IV (BSIV) emission standards for new vehicles in April 2017, and the more recent Bharat Stage VI (BSVI) emissions and fuel quality standards in 2020. The current emissions inspection programme is the Pollution under Control Certificate (PUC) system, however, detailed data on the number of PUC centres in each city, the number of vehicles tested at each centre, the pass and fail status of the vehicles, etc. are not available. The government is establishing vehicle inspection and maintenance centres for commercial vehicles in Odisha, with six automated vehicle testing centres expected in the state. Other target actions include regulating the movement of heavy duty vehicles (heavy goods vehicles, HGVs), phasing out older vehicles, a sticker system for vehicles (under the Union Ministry of Road Transport and Highways (MoRTH) Colour Coded High Security Registration Plates (HSRP) Hologram Stickers programme), a clean fuel initiative (with a focus on compressed natural gas, CNG), and other mode changes such as increasing public transport and electromobility.

A natural gas vehicle programme has become a possibility in Bhubaneswar and Cuttack. The Union Ministry for Petroleum and Natural Gas (MoPNG) has introduced two Compressed Natural Gas (CNG) stations in Cuttack and it is planned that 20 CNG stations will be commissioned in the twin cities of Bhubaneswar and Cuttack. A short-term priority action in the CAAP is to expand the CNG refuelling infrastructure for delivery and use, as well as transferring all auto rickshaws and a considerable proportion of taxis and buses to run on CNG.

3.2 Mexico

3.2.1 Salamanca, Celaya, and Irapuato, Mexico

The municipalities of Salamanca, Celaya and Irapuato lie within the state of Guanajuato, in central Mexico. One of the main instruments for air quality management in Mexico are the ProAire programmes, which develop specific actions for air quality management. Improvements have been made in Salamanca due to previously implemented measures through ProAire, with exceedances of the PM_{10}

[31] Table 1D, Comprehensive Action Plan for Clean Air for Non-Attainment Cities of Odisha, Air Quality Monitoring Committee, Government of Odisha – Cuttack, 2018.
[32] Graph 1, Comprehensive Action Plan for Clean Air for Non-Attainment Cities of Odisha, Air Quality Monitoring Committee, Government of Odisha – Cuttack, 2018.
[33] Graph 2, Comprehensive Action Plan for Clean Air for Non-Attainment Cities of Odisha, Air Quality Monitoring Committee, Government of Odisha – Cuttack, 2018.

standards reducing from 33 days in 2006 to eight days in 2012.[34] Salamanca exceeds the annual PM_{10} standard (40 µg/m^3)[35] the most often and to a greater extent than Irapuato and Celaya.[36]

Based on data from 2008, Celaya and Iarpuato have similar numbers of registered vehicles (108,886 and 104,293 respectively). Salamanca has fewer vehicles (61,273). Celaya and Irapuato contribute more to PM_{10} and $PM_{2.5}$ emissions overall than Salamanca (more than double the value).[37] The three cities show a downward trend in PM_{10} concentrations between 2005 – 2009, but the values rose again from 2010 onwards.[38] From 2003 – 2011, Celaya reported an increase of NOx concentrations of 136%, Irapuato 28% and Salamanca 20%.[39]

PM_{10} emissions are generated mainly by the traffic of vehicles on unpaved roads, tillage activities and the burning of agricultural residues.[40] Within the category of mobile sources, diesel trucks and urban buses contribute the most to PM_{10}, $PM_{2.5}$ and NOx emissions in the region.[41] Emissions from transport are monitored using the State Air Quality Monitoring Network. The network consists of 13 machines, located in the urban centres of key cities in the state: Celaya, Irapuato, Salamanca, Silao and León. The first monitoring network was installed in Salamanca in the year 2000, which made it possible to identify the need for air quality improvement actions. Currently, Salamanca, Celaya, and Irapuato each have three stations which are equipped with continuous gas and particulate analysers.[42] A barrier to air quality management in the three cities is the low number of monitoring stations, and lack of consistency in the data, which makes it hard to assess the air quality situation.[43]

The Management Program to Improve Air Quality considers vehicular pollution control under four measures; promoting sustainable mobility policies;[44] promoting actions to reduce points of road congestion;[45] discouraging the use of private vehicles;[46] and promoting the strengthening of freight transport routes and its modernization.[47] The development of mass transport infrastructure and non-motorised mobility are considered important actions, as vehicle emissions represent a significant contribution to pollution in the cities.

3.2.2 León, Mexico

The León Metropolitan Area (ZML), consisting of the municipalities of Purísima del Rincón, San Francisco del Rincón, Silao, and León, also lies within the state of Guanajuato in central Mexico. A growth in the vehicle fleet alongside expansion of various industrial, commercial, and service industry activities have contributed to air quality degradation in the area. ZML regularly exceeds the annual NAAQS for PM_{10}.[48]

The State Air Quality Monitoring Network of Guanajuato, as described above, consists of 13 automatic stations located in the five main urban centres of the state: Celaya, Irapuato, Salamanca, Silao and León. In ZML, the network is made up of four automatic stations (three located in the city of León and one in Silao), run by the Technological University of León.[49] Each station is equipped with gas and particle analysers and meteorological sensors.

Source apportionment conducted under the ProAire programme shows that within León, heavy goods vehicles represent a large source of $PM_{2.5}$ emissions, and PM_{10} can be attributed partly to unpaved

[34] P. 6, Management Program to Improve Air Quality in Salamanca, Celaya, and Irapuato, 2013.
[35] NORMA Official Mexicana NOM-025-SSA1-2014, Salud ambiental. Valores límite permisibles para la concentración de partículas suspendidas PM10 y PM2.5 en el aire ambiente y criterios para su evaluación, 2014, available online at: http://dof.gob.mx/nota_detalle.php?codigo=5357042&fecha=20/08/2014
[36] Graph 28 and 29, Management Program to Improve Air Quality in Salamanca, Celaya and Irapuato, 2013.
[37] Table 66, Management Program to Improve Air Quality in Salamanca, Celaya and Irapuato, 2013.
[38] Graph 60, Management Program to Improve Air Quality in Salamanca, Celaya and Irapuato, 2013.
[39] Graph 58, Management Program to Improve Air Quality in Salamanca, Celaya and Irapuato, 2013.
[40] P. 22, Management Program to Improve Air Quality in Salamanca, Celaya and Irapuato, 2013.
[41] P. 25, Management Program to Improve Air Quality in Salamanca, Celaya and Irapuato, 2013.
[42] P. 33, Management Program to Improve Air Quality in Salamanca, Celaya and Irapuato, 2013.
[43] P. 57, Management Program to Improve Air Quality in Salamanca, Celaya and Irapuato, 2013.
[44] P. 135, Management Program to Improve Air Quality in Salamanca, Celaya and Irapuato, 2013.
[45] P. 136, Management Program to Improve Air Quality in Salamanca, Celaya and Irapuato, 2013.
[46] P. 137, Management Program to Improve Air Quality in Salamanca, Celaya and Irapuato, 2013.
[47] P. 138, Management Program to Improve Air Quality in Salamanca, Celaya and Irapuato, 2013.
[48] Graph 48, Management Program to Improve Air Quality in the Léon Metropolitan Area, 2013.
[49] P. 36, Management Program to Improve Air Quality in the Léon Metropolitan Area, 2013.

roads and construction sites. Meanwhile, CO and NOx largely come from mobile sources (vehicle emissions), particularly diesel trucks over 3.5 tonnes.[50] Remodelling and construction work in the city has led to generation of dust, which contributes to the level of PM.[51] According to the recent ProAire report, vehicles represent 2.95% of PM_{10}, 7.94% of $PM_{2.5}$, 98.57% of CO and 79.74% of NOx in ZML.[52]

León has an effective public transport system, with almost 40% of the mode split being public transport,[53] having implemented a Bus Rapid Transport System (BRT) in 2003, which covers almost half the daily rides in the city.[54] This system contributes to a very low public transport energy consumption of 0.1 megajoules per passenger kilometre.[55]

The Management Program to Improve Air Quality in ZML considers vehicular pollution control under the same four measures as those in Salamanca, Celaya and Irapuato; promoting sustainable mobility policies;[56] promoting actions to reduce points of road congestion;[57] discouraging the use of private vehicles;[58] and promoting the strengthening of freight transport routes and its modernisation.[59] Private vehicles represent 50% of the vehicle fleet of the State, so it is seen as important to promote a reduction in these vehicles while offering alternatives, providing social, economic, and environmental benefits such as reduced travel times and improved air quality.[60] The State government has launched the Environmental Management System for Clean Transport of Guanajuato, a tool that when implemented will help to reduce emissions from all means of diesel or gasoline transportation. Through this tool, individuals and transport companies can join a programme which sets out the technical requirements to reduce emissions from vehicle usage.[61]

[50] P. 70-75, Management Program to Improve Air Quality in the Léon Metropolitan Area, 2013.
[51] P. 59, Management Program to Improve Air Quality in the Léon Metropolitan Area, 2013.
[52] P. 119, Management Program to Improve Air Quality in the Léon Metropolitan Area, 2013.
[53] Tool for rapid assessment of city energy – León, Guanajuato, México, 2012, P.23, available online at: https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/TRACE_Mexico_Leon_Optimized.pdf
[54] Tool for rapid assessment of city energy – León, Guanajuato, México, 2012, P.3, available online at: https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/TRACE_Mexico_Leon_Optimized.pdf
[55] Tool for rapid assessment of city energy – León, Guanajuato, México, 2012, P.25, available online at: https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/TRACE_Mexico_Leon_Optimized.pdf
[56] P. 118, Management Program to Improve Air Quality in the Léon Metropolitan Area, 2013.
[57] P. 119, Management Program to Improve Air Quality in the Léon Metropolitan Area, 2013.
[58] P. 120, Management Program to Improve Air Quality in the Léon Metropolitan Area, 2013.
[59] P. 121, Management Program to Improve Air Quality in the Léon Metropolitan Area, 2013.
[60] P. 121, Management Program to Improve Air Quality in the Léon Metropolitan Area, 2013.
[61] P.1, Sistema de gestion ambiental “SIGA” Transporte Limpio Guanajuato, 2021. (https://smaot.guanajuato.gob.mx/sitio/calidad-del-aire/156/Transporte-Limpio-SIGA)

4 Actions to reduce the impacts of transport emissions

The following sections provide a summary of the types of measures that can be implemented to mitigate the impacts of transport emissions, including background information, mechanisms for implementation, and effectiveness. Best practice examples from cities in Europe and Asia have been included, and where possible, specific information relating to costs, funding streams, timescales and impacts have been provided. The cities included in this review are as follows:

- European cities: Berlin, Bonn, Cambridge, Copenhagen, Essen, Dortmund, Hamburg, Helsinki, Herrenberg, Mannheim, Oxford, Reutlingen, and Stockholm.
- Rest of the World cities: Dhaka, Kolkata, Jakarta, Lahore, and Singapore.

The measures have been grouped according to the method as to which they reduce emissions, for example direct emission control (such as driving bans and emissions standards), new technologies (such as electric buses and taxis, and e-delivery vehicles) and mode shift (such as cycle networks, mobility management and car sharing). At the end of each section, the measures within that group have been evaluated according to the following criteria:

- **Which pollutants are affected?** – The pollutants we would expect to be impacted by the measure are listed.
- **Air quality impact** – A score of between 1 and 5 is assigned based on the expected impact on emissions of pollutants, as well as the impact on measured concentrations and other key indicators, such as smog. For example, collection of air quality data would score a 1, and a Low Emission Zone would score a 5.
- **Costs** – A score of between 1 and 5 is assigned based on the expected overall cost. A measure expected to give a cost benefit would score a 5. A measure with zero cost scores a 4. A measure with an estimated cost of more than zero but less than INR 10 million scores a 3. A measure with an estimated cost of between INR 10 million and INR 100 million scores a 2. A measure with an estimated cost of greater than INR 100 million scores a 1.
- **Co-benefits** – A score of between 1 and 5 is assigned based on the expected number and scale of co-benefits. If a measure has multiple co-benefits that are likely to be felt by a significant proportion of the population, it scores a 5. If a measure has few or no identifiable co-benefits then it scores a 1.
- **Innovation** – A score of between 1 and 5 is assigned based on the novelty of the measure. For example, air quality monitoring networks are well-established in most cities so would only score a 1. A new automated, dynamic traffic system might score a 5.
- **Reliance on other measures** – A score of between 1 and 5 is assigned based on the impact a measure can have independent of other measures. A measure that is reliant on other measures to achieve an improvement in air quality (for example, air quality forecasting) would have a low score. A measure that, alone, is likely to achieve a significant improvement in air quality (for example, enforcement of emissions standards) would score a 5.
- **Prospective timescale** – A score of between 1 and 5 is assigned based on the expected time taken to see a benefit to air quality. A measure with an immediate benefit (e.g. direct removal of emissions from a fleet of vehicles) would score a 5. A measure likely to be effective within one-year scores a 4. A measure likely to be effective within two to five years scores a 3. A measure likely to be effective within five to ten years scores a 2. A measure that is not likely to be effective for at least ten years scores a 1.

The evaluation of measures is presented in a table at the end of each group of measures. The evaluation takes into account the general information about the measure, the best practice case studies we have looked at, and consideration of the requirements of the Indian cities. The evaluation is the result of the expert analysis of the measures by Ricardo Energy and Environment, based on the information available at the time. The result of the evaluation will be helpful in providing guidance as to which measures are likely to be the most useful for the Indian cities of Cuttack and Bhubaneswar, and those that may be recommended for implementation as part of the Triangular Cooperation Project.

4.1 Direct emission control

4.1.1 Driving bans / Low Emission Zones and congestion charges

Driving bans, Low Emissions Zones (LEZs) and congestion charges all operate to encourage the more polluting vehicles within a city (such as those that run on diesel) to become cleaner, by making it either illegal to enter certain areas with those vehicles, or more expensive and less attractive than sustainable alternatives such as Low Emission Vehicles (LEVs), public transport or walking and cycling.[62,63]

Some cities may have the power to implement driving bans / LEZs or other charges, however, many require permission from the national government to do so. For example, the city of Zurich in Switzerland was ranked top in the European 'Soot Free Cities' 2015 ranking;[64] however, an area the city did not score well in was 'Low Emission Zones and Bans of High Emitters'. As there are no national regulations promoting LEZs, Zurich lacks the power to create them, and when the city requested to cooperatively introduce a LEZ in the local air quality plan, they were not supported. The advice from the Soot Free Cities ranking is that LEZs should be introduced as early as possible, should cover a significant proportion of the city, aim at ambitious emissions standards (at least Euro 4) and be strictly enforced. Bans of high emitters might relocate pollutants instead of reducing them, so this needs to be considered during the planning process.

Congestion charges have been considered in Helsinki, the capital of Finland, due to the potential benefits to health from reduced pollution. In the region, this is seen as an effective potential measure to reduce traffic, influence modal shift and therefore improve air quality. However, this measure requires political decisions to be made, amendments to the law to allow for revenue from the charges as well as an effective public transport system to be in place. Studies have taken place in Helsinki to assess the implications of a charge, such as the Helsinki Region Transport System Plan[65] and the Helsinki Region Congestion Charge Statement,[66] which found that congestion charging helps achieve the objectives set for the Helsinki region transport system better than a transport system without congestion charging. A charge is estimated to reduce the volume of passenger car traffic by around 20%.

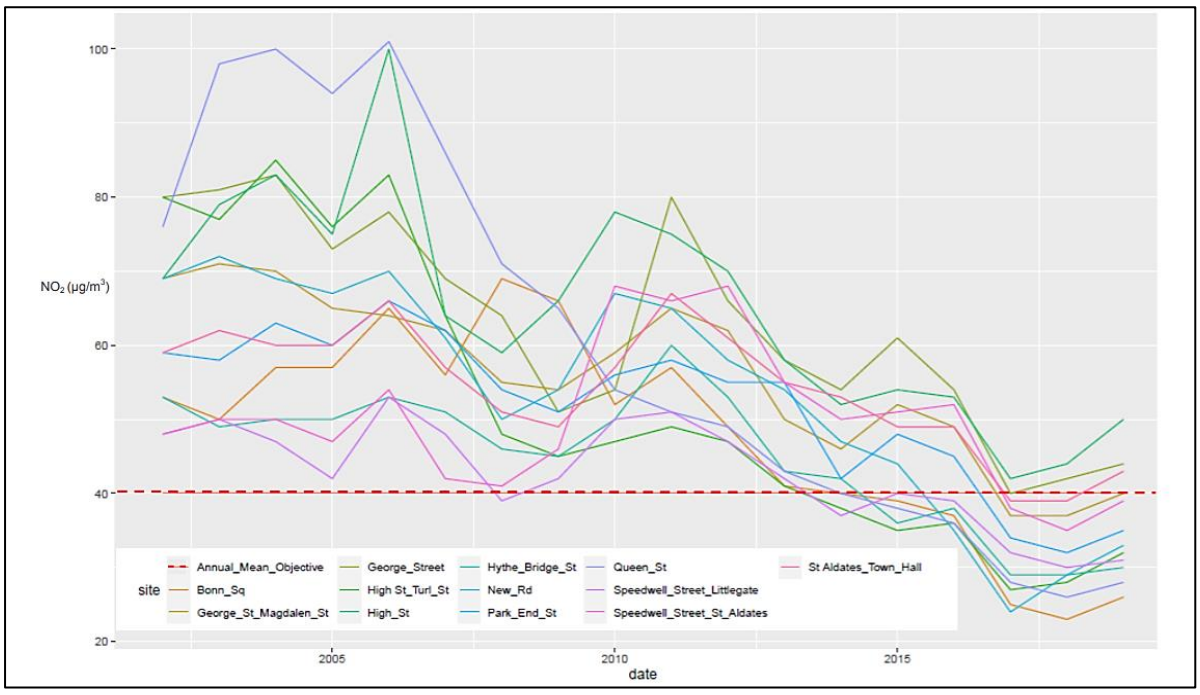
In Stockholm, Sweden, there has been a LEZ for heavy goods vehicles (HGVs) covering the entire city centre since 1996.[67] Diesel HGVs and buses over six years old are required to meet at least Euro II standards; diesel HGVs less than eight years old must meet either Euro II or III standards; Euro IV vehicles will be phased out before 2017 and Euro V HGVs before 2021. As the LEZ addresses only part of the total vehicle fleet, it has a limited scope, although some promise with the timetable for phasing out Euro IV & V vehicles. Stockholm also has a congestion tax and bridge taxes (used to maintain the bridges), both implemented by the Swedish Transport Agency. The congestion tax in Stockholm and Gothenburg is charged on weekdays during the day. The maximum charge of congestion tax in Stockholm is 105 SEK (Swedish Krona, approximately INR 900) and tax is not charged on Saturdays, Sundays, public holidays, the day before a public holiday or during the month of July. The price per bridge crossing varies between 9 and 35 SEK (approximately INR 80 – INR 300), depending on the time and the direction of crossing. Bridge tolls are charged 24 hours a day on the bridges across Sundsvallsfjärden and Motalaviken. The amount varies between 5 and 20 SEK (approximately INR 40 – INR 170) per crossing, depending on the size of the vehicle and direction. Stockholm has estimated that around 25 – 30 premature deaths per year are avoided due to congestion charges.

In the United Kingdom, Oxford introduced a Euro 5 bus-based LEZ in 2014, as buses have been identified as the main source of emissions in the city centre. Dramatic air quality improvements in Oxford

[62] Low Emission Zone (2020), UK, available online at: https://tfl.gov.uk/modes/driving/low-emission-zone
[63] Congestion Charge Factsheet (n.d), available online at: http://content.tfl.gov.uk/congestion-charge-factsheet.pdf.pdf
[64] European City Ranking 2015, Best practices for clean air in urban transport, 2015, http://www.sootfreecities.eu/sootfreecities.eu/public/
[65] Helsinki Region Transport System Plan (2015), available online at: https://www.hsl.fi/sites/default/files/uploads/hlj_2015_puiteohjelma_2012_27.pdf
[66] Helsinki Region Congestion Charge Statement follow-up (2011), available online at: https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/78137/Helsinki_Region_Congestion_Charges_-_English_Summary.pdf?sequence=2&isAllowed=y
[67] European City Ranking 2015, Best practices for clean air in urban transport, 2015, http://www.sootfreecities.eu/sootfreecities.eu/public/

have been made possible by the original Oxford Transport Strategy (OTS) in 1999, which restricted general traffic and left buses as the dominant source of air pollution in the city centre.[68] This has made transport emissions easier to tackle and the bus LEZ more effective, since buses constitute a large portion of the vehicle mix. The bus LEZ scheme was due to be upgraded to a Euro 6 bus LEZ from December 2020 but has been delayed due to the pandemic and will now be implemented in December 2021. A reduction in NO_2 levels seen over the period 2009-2019 (Figure 2) have largely been attributed to the introduction of the LEZ for buses and investment in buses with Euro 6 engines.[69] By May 2020, bus operators in Oxford had already made good progress towards meeting the Euro 6 standards with almost three-quarters of the bus fleet already compliant, and the city had introduced its first electric double-decker bus which is used for sightseeing.[70] The bus LEZ in Oxford has been supported by government funding such as the Clean Bus Technology Fund, used to upgrade buses to newer technology.[71] Under an updated Air Quality Action Plan (AQAP) in 2013, Oxford's emissions reduction measures looked to further develop the bus-related LEZ by creating a freight LEZ, aiming to reduce total freight transport NOx by 45%.[72] As shown in Figure 2, air quality in many areas of the city has plateaued which suggests the need for further, stronger measures to be implemented. Taking this into account, in 2020 Oxford applied for funding to become the first city in England to use an all-electric bus fleet, with the potential to win £50 million in government funding toward this development.[73]

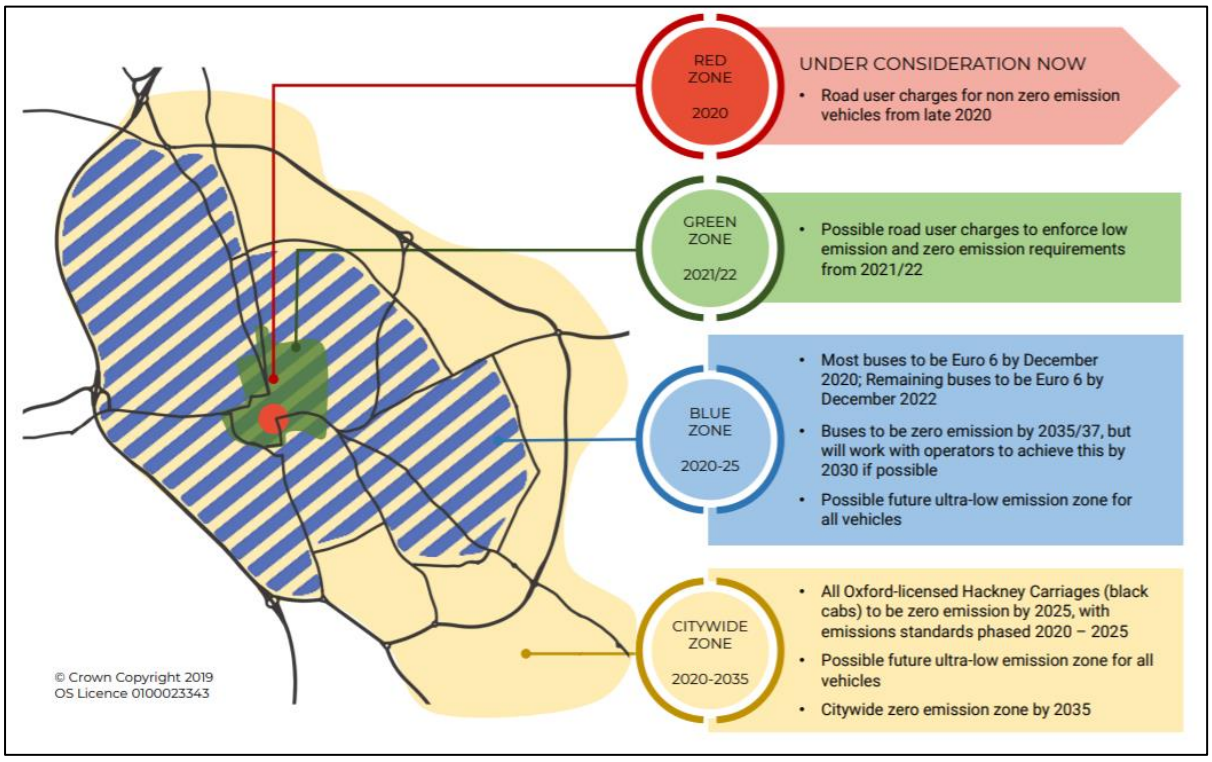
Figure 2: Long term trends in annual mean NO_2 ($\mu g/m^3$) at diffusion tube monitoring locations in Oxford, from 2003-2019.[74]



[68] Connecting Oxfordshire volume 8 part i - Oxford Transport Strategy, 2015, available online at: https://www.oxfordshire.gov.uk/residents/roads-and-transport/connecting-oxfordshire/area-strategies
[69] 2019 Air Quality Annual Status Report (ASR), 2019, p.iii, available online at: https://www.oxford.gov.uk/info/20298/air_quality_data/1216/air_quality_annual_status_reports
[70] Updates to emission standards for Hackney Carriages and timeline for buses for the Oxford Zero Emission Zone following coronavirus pandemic, 2020, available online at: https://www.oxford.gov.uk/news/article/1413/updates_to_emission_standards_for_hackney_carriages_and_timeline_for_buses_for_the_oxford_zero_emission_zone_following_coronavirus_pandemic
[71] Clean Bus Technology Fund, 2018, available online at: https://www.gov.uk/government/collections/clean-bus-technology-fund
[72] Oxford Low emission strategy (2013), p.20-21, available online at: https://www.oxford.gov.uk/downloads/download/156/low_emission_strategy
[73] Oxford applies for funding to become Britain's first all-electric bus town, 2020, available online at: https://news.oxfordshire.gov.uk/oxford-applies-for-funding-to-become-britains-first-all-electric-bus-town/
[74] 2019 Air Quality Annual Status Report (ASR), 2019, p.33, available online at: https://www.oxford.gov.uk/info/20298/air_quality_data/1216/air_quality_annual_status_reports

Planned replacement and retrofitting of current buses forms part of a pilot for a Zero Emission Zone (ZEZ) in Oxford, starting in August 2021 in the city centre. This is to be developed and expanded throughout the city between 2020 – 2035, as illustrated in Figure 3. Within the ZEZ, only zero emission vehicles would be able to drive free of charge. A charging scheme was selected, as it provides an effective incentive for zero emission transport, but can be adapted to accommodate a range of needs within the city. For example, local buses and transport for local businesses would not be charged within the ZEZ.[75] Under the ZEZ plans, taxis are also required to convert to zero-emission vehicles between 2020 and 2025, with drivers only able to get a licence in 2025 if they have a zero-emission cab.[76]

Figure 3: ZEZ phasing in Oxford, as presented in the Oxford Zero Emission Zone Summary (2020)[77]



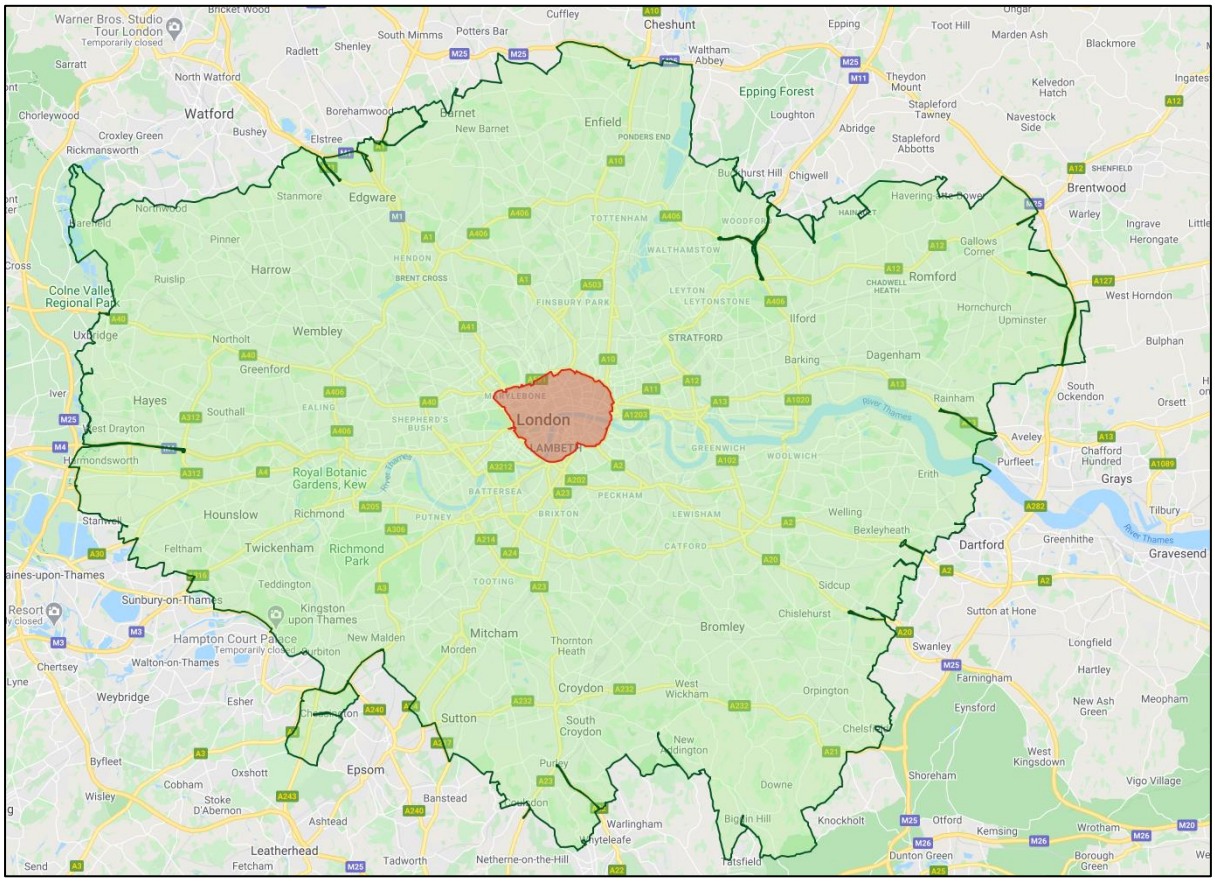
In Cambridge (UK), a LEZ, also known as a 'Clean Air Zone' (CAZ) is under consideration as part of the local AQAP, having designated the city centre as an air quality management area (AQMA) due to high levels of nitrogen dioxide.[78] Cambridge has decided upon a 'Class D' CAZ which includes charging for all vehicle types, based on the findings of their CAZ feasibility study.[79] This CAZ would promote low emission transport and reduce access for more polluting through potential actions such as; only permitting access to low emission vehicles, a congestion charge, installing EV charging points and improving emissions standards in public transport and HGVs. Within the 2018 – 2023 AQAP, the CAZ was originally anticipated for introduction from 2020, depending on results from the feasibility study.[80]

In London, a LEZ has been in place since 2008. To begin with, the LEZ applied to commercially operated diesel vehicles including buses, coaches, and lorries, and was expanded in 2012 to include diesel vans, minibuses, horseboxes, motor caravans, utility vehicles and pick-up trucks (known as

[75] Oxford Zero Emission Zone (2020), available online at: https://www.oxfordshire.gov.uk/sites/default/files/file/roads-and-transport-connecting-oxfordshire/ZEZ_update_Jan2020.pdf
[76] Updates to emission standards for Hackney Carriages and timeline for buses for the Oxford Zero Emission Zone following coronavirus pandemic, 2020, available online at: https://www.oxford.gov.uk/news/article/1413/updates_to_emission_standards_for_hackney_carriages_and_timeline_for_buses_for_the_oxford_zero_emission_zone_following_coronavirus_pandemic
[77] Oxford Zero Emission Zone, 2020, available online at: https://www.oxfordshire.gov.uk/sites/default/files/file/roads-and-transport-connecting-oxfordshire/ZEZ_update_Jan2020.pdf
[78] Clean air zone Cambridge (2021), available online at: https://www.cambridge.gov.uk/clean-air-zone
[79] Cambridge Clean Air Zone feasibility study (2018), available online at: https://consultcambs.uk.engagementhq.com/1836/documents/2050
[80] Cambridge City Council Air Quality Action Plan 2018 - 2023 (2019), p.51-78, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf

'specialist vehicles'). The LEZ covers most of Greater London (see Figure 4) and operates 24 hours a day, every day of the year.[81] The emissions standards and charges for the LEZ were as follows: for vans and 'specialist vehicles' a charge of £100 per day is incurred if the Euro 3 standard for PM is not met; for buses, coaches and minibuses over 5 tonnes, as well as heavy goods vehicles, lorries and vans over 3.5 tonnes, a £200 daily charge is incurred if the Euro IV standard for PM is not met. However, from March 2021 the LEZ is becoming stricter.[82] No change applies to vans and 'specialist vehicles', but for buses, coaches, and minibuses over 5 tonnes, as well as heavy goods vehicles, lorries, and vans over 3.5 tonnes, Euro VI standard for NOx and PM must be met to avoid a charge. A charge of £100 per day is incurred if these vehicles meet Euro IV or V standard (for PM only) and a charge of £300 per day is incurred if the original standard of Euro IV is not met (for PM only).

Figure 4: Map showing the London LEZ (green) and the current ULEZ (red) areas[83]



An Ultra-Low Emission Zone (ULEZ) was launched in London in April 2019. The ULEZ currently covers an area of central London where the Congestion Charge also applies, but is due to be expanded significantly in October 2021 (see Figure 5). The ULEZ standards for the existing central London zone, and when the zone expands, are:

- Euro 3 (NOx) for motorcycles, mopeds, motorised tricycles, and quadricycles;
- Euro 4 (NOx) for petrol cars, vans, and other specialist vehicles (up to and including 3.5 tonnes) and minibuses (up to and including 5 tonnes);
- Euro 6 (NOx and PM) for diesel cars, vans, and other specialist vehicles (up to and including 3.5 tonnes) and minibuses (up to and including 5 tonnes);

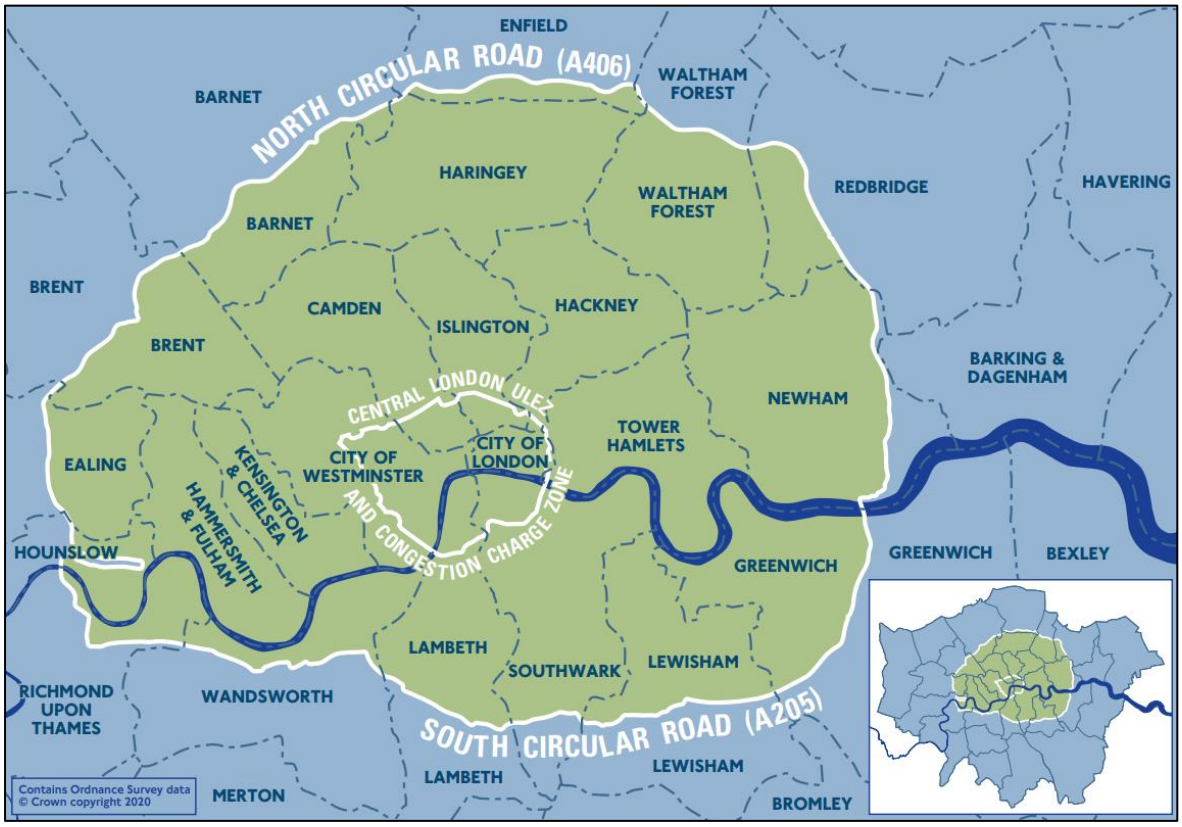
[81] Low Emission Zone, TfL, https://tfl.gov.uk/modes/driving/low-emission-zone
[82] London's air quality schemes and Congestion Charge, TfL, available online at: https://lruc.content.tfl.gov.uk/ulez-lez-comparison-table.pdf
[83] LEZ: Where and when, TfL, available online at: https://tfl.gov.uk/modes/driving/low-emission-zone/about-the-lez?intcmp=2263

- Euro VI (NOx and PM) for buses, coaches, and minibuses (over 5 tonnes), as well as heavy goods vehicles, lorries, vans, and specialist heavy vehicles (over 3.5 tonnes).[84]

For motorcycles, mopeds, motorised tricycles, quadricycles, cars, vans, other specialist vehicles (up to 3.5 tonnes) and minibuses (up to 5 tonnes), the daily charge for not meeting the above Euro standards is £12.50.[85] For buses, coaches and minibuses (over 5 tonnes), and heavy goods vehicles, lorries, vans, and specialist heavy vehicles (over 3.5 tonnes), the daily charge is £100. The ULEZ is denoted by road signs at its boundaries, and all information relating to the charges, plus a vehicle checker (to find out if your vehicle meets emissions and safety standards required to drive in London, or if you need to pay a daily charge) are available online.[86]

Significant reductions in pollutant concentrations in central London have been attributed to the London ULEZ. A progress report covering the first six months of the ULEZ's implementation found that roadside concentrations of NO_2 were 36% lower (in September 2019) than they were in (February) 2017, corresponding to a reduction of 32 $\mu g/m^3$.[87] When considering the proportion of vehicles travelling in the zone that comply with the ULEZ standards, the average proportion of compliant vehicles was 77%, six months into the scheme, compared with just 39% in 2017 (when the ULEZ was not in place). There was also an estimated reduction in general traffic flows of between 3% - 9%, compared to during 2018. More recent figures estimate that the current compliance rate within the zone is now at 80%, with a reduction of roadside NO_2 concentrations of 44% compared to 2017 levels.[88]

Figure 5: Map showing the current London ULEZ (green) and the expansion, due in October 2021[89]



Co-benefits of driving bans and LEZs include reduced traffic congestion and emissions, leading to improved air quality and health benefits, reduced noise pollution, and lower GHG emissions.

[84] ULEZ expansion, TfL, https://tfl.gov.uk/modes/driving/ultra-low-emission-zone/ulez-expansion?intcmp=53057
[85] London's air quality schemes and Congestion Charge, TfL, available online at: https://lruc.content.tfl.gov.uk/ulez-lez-comparison-table.pdf
[86] Check your vehicle, TfL, https://tfl.gov.uk/modes/driving/check-your-vehicle/
[87] Central London Ultra Low Emission Zone – Six Month Report, Greater London Authority, 2019, available online at: https://www.london.gov.uk/sites/default/files/ulez_six_month_evaluation_report_final_oct.pdf
[88] ULEZ expansion, TfL, https://tfl.gov.uk/modes/driving/ultra-low-emission-zone/ulez-expansion
[89] Simple map of ULEZ expansion area, TfL, https://lruc.content.tfl.gov.uk/simple-map-of-ulez-expansion-area.pdf

4.1.2 Strict emissions standards and enforcement in private vehicles

Emissions standards for vehicles are set in order to limit the amount of pollutants being released from a vehicle to an 'acceptable' level. Above this emission performance standard, other technologies are required to limit the vehicle emissions. This regulatory technique traditionally had a focus on carbon dioxide (CO_2) and hydrocarbons (HC), however, many standards now include a range of other pollutants such as nitrogen oxides (NOx), sulphur oxides (SOx), and particulate matter (PM_{10} and $PM_{2.5}$). There are three main sets of emissions standards: American (United States), Japanese, and European, although there are others too. As per the Indian National Clean Air Plan (NCAP)[90], the state of Odisha implemented the Bharat Stage IV (BSIV) emission standards for new vehicles in April 2017, followed by Bharat Stage VI (BSVI) norms and fuels in April 2020. The BSVI norms are set to reduce emissions from new vehicles by 80–90%.

The current in-use emissions inspection programme in India is the Pollution under Control Certificate (PUC) system. Currently, under this programme, idling CO and hydrocarbon (HC) concentrations are measured in petrol vehicles and smoke density is measured in diesel vehicles. Assessments have shown that there are quality control challenges with regard to the testing methods, calibration of equipment and overall compliance with the programme. Newer generation vehicles will be equipped with more advanced emissions control systems, meaning that improvements in emissions inspection and maintenance will be needed in Bhubaneswar and Cuttack.

The Singapore National Environment Agency (NEA) has enforced a number of vehicle emissions standards since January 2014, when the requirement for all in-use diesel driven vehicles to achieve a smoke opacity reading of 40 Hartridge Smoke Units or below during vehicle inspection was introduced. Since then, from September 2017 all new petrol vehicles, and from 1 January 2018 all new diesel vehicles, have had to meet Euro 6/VI emission standards.[91] All new vehicles (as well as used imported vehicles) must comply with Euro 6/VI emission standards and motorcycles must comply with Euro 4 emission standards. In-use vehicle emission standards (which apply to any vehicle registered in Singapore) are described in the Environmental Protection and Management (Vehicular Emissions) Regulations[92] - the emissions standards for vehicles are provided in the Fifth Schedule and standards for vehicular fuel quality are provided in the Eighth Schedule. Enforcement is carried out by vehicle inspections; accredited bodies are provided online and vehicle owners may be required to provide proof of their vehicle's emission standard.[93] Any person who is guilty of an offence under the Regulations can be liable to a fine up to S$2,000 (approximately INR 109,000) and, in the case of a second or subsequent offence, to a fine up to S$5,000 (approximately INR 273,000).

Zurich, the capital city of Switzerland, was named the number one city in the European 'Soot Free Cities' 2015 ranking.[94] The city enforces pollution limit values for CO, HC, NOx and particles (by mass and number) and states these are one of the most important methods in reducing emissions from traffic.[95] Switzerland set its own limit values on emissions from vehicles from 1982 to 1995, but since 1995 has amended the limits to be in line with the EU. For private vehicles, Euro 5/V and 6/VI standards apply for passenger vehicles with diesel or direct-injection petrol engines. It is estimated that with closed particle filters, diesel soot in the exhaust gases can be reduced by up to 99%. There is still work to be done for motorcycles, as much less stringent emission standards apply than for passenger cars. Motorcycles therefore still emit significantly more pollutants than passenger cars. There are very strict emissions regulations for mopeds, however, unlike motorcycles they do not have to comply with the

[90] National Clean Air Programme, Ministry of Environment, Forest & Climate Change, Government of India, 2019.
[91] Air Quality in Singapore, https://www.nea.gov.sg/our-services/pollution-control/air-pollution/air-quality#:~:text=Singapore%20enjoys%20better%20air%20quality,range%20for%20much%20of%202019
[92] Environmental Protection and Management (Vehicular Emissions) Regulations for Singapore (last updated in January 2021), available online at: https://sso.agc.gov.sg/SL/EPMA1999-RG6?DocDate=20120629&ViewType=Pdf&_=20200723162422
[93] Accredited Testing Bodies For Source Emission Tests in Singapore, https://www.nea.gov.sg/our-services/pollution-control/air-pollution/air-quality/accredited-testing-bodies-for-source-emission-tests
[94] European City Ranking 2015, Best practices for clean air in urban transport, 2015, http://www.sootfreecities.eu/sootfreecities.eu/public/
[95] Emissions regulations for motor vehicles in Zurich, https://www.bafu.admin.ch/bafu/de/home/themen/luft/fachinformationen/massnahmen-zur-luftreinhaltung/massnahmen-zur-luftreinhaltung-beim-strassenverkehr.html

limit values for five years, or over 30,000 km. This means many mopeds do not comply with the limit values when in operation. The EU has proposed a roadmap with gradual reductions in exhaust emission limits; from approximately 2021, the same emissions regulations will apply to light and heavy motorcycles as to passenger cars.

The Road Traffic Department at the Federal Roads Office (FEDRO) in Zurich is responsible for enforcing the emissions regulations for road traffic. There are test cycles and durability requirements (over certain time periods and distances) for the emissions limit values, and these are checked periodically by the road traffic authorities (FEDRO). Finally, there is also an exhaust gas maintenance check that vehicles are obligated to go through every two years, unless they have an on-board diagnosis system. Again, this is less stringent for motorcycles and mopeds, which are only obligated to complete a periodic vehicle inspection, not an emissions inspection. The 'Ordinance on the technical requirements for road vehicles' (VTS) regulates the criteria for classifying road vehicles, the registration test, inspection and exhaust maintenance of road vehicles, and the technical requirements for road vehicles.[96]

Stockholm, the capital city of Sweden, achieved the rank of fourth in the European 'Soot Free Cities' 2015 ranking.[97] The Swedish Transport Agency is responsible for regulations on vehicle exhaust fumes and regulations on fuel.[98] All new cars (as well as LGVs, and HGVs over 3.5 tonnes) are classified according to their exhaust emissions. Since 1993, cars have been placed in one of three environmental classes. The requirements have since been tightened in stages; from 2002 new environmental classes were introduced: classes 2000, 2005, 2008, EEV (Enhanced Environmentally friends Vehicle), El (electric) and Hybrid. New cars that are registered must meet Euro 5 and Euro 6 requirements. As a complement, they can also be classified as Electricity, Hybrid and Charging Hybrid if they are equipped with such technology. In Sweden, the pollutants that determine the emission standard are CO, HC, NOx, and particles (the same as for Zurich). The emission classes are regulated by the Exhaust Gas Purification Act (2011: 318) for new vehicles registered from 1 May 2011. Older vehicles are classified in environmental class according to the repealed Act (2001: 1080) on motor vehicle exhaust purification and motor fuels. In both cases, the classification is linked to the EU regulations on exhaust emissions. The current exhaust emission requirements are based on exhaust gas testing according to European testing methods. For passenger cars, the entire vehicle is tested and approved in accordance with the methods and provisions of EU Regulation 715/2007.

In Lahore, the capital of Pakistan, the Pakistan Environmental Protection Council (PEPC) revised emission standards for all new and in-use vehicles within the National Air Quality Standards (NAQS) in 2009.[99] A suggested policy option in Pakistan is the introduction of Euro 2 or above standards on all locally assembled and imported private automobiles and light-duty utility vehicles.[100] The Euro 2 standards are also known in Pakistan as the National Environmental Quality Standards (NEQS) – the approved standards enforced by Pak-EPA (Pakistan Environmental Protection Agency) since 2010. This measure is expected to reduce PM emissions quite substantially compared with Euro 1 standards, but is far behind the current standards in European cities. Euro standards can be mandated on new diesel vehicles and second-hand imports. The NEQS for ambient air cover several major pollutants: sulphur dioxide (SO_2); NOx; O_3; suspended particulate matter (SPM); fine particulate matter ($PM_{2.5}$); Pb; and CO. Retrofitting Euro 1 or pre-Euro 1 diesel vehicles with PM control technologies such as a diesel oxidation catalyst (DOC) generally reduces PM emissions by 20–30%.[101] In the long-term, adopting fuel efficiency and emissions standards for vehicles in line with Euro 2 or 3 and gradually

[96] Ordinance on the technical requirements for road vehicles (VTS), Swiss Federal Council, 1995 (last updated May 2019), available online at: https://www.fedlex.admin.ch/eli/cc/1995/4425_4425_4425/de
[97] European City Ranking 2015, Best practices for clean air in urban transport, 2015, http://www.sootfreecities.eu/sootfreecities.eu/public/
[98] Exhaust regulations for motor vehicles in Sweden, https://transportstyrelsen.se/sv/vagtrafik/Miljo/Luftkvaliet-i-tatorter/Avgaser/
[99] Cleaning Pakistan's Air, Policy Options to address the cost of outdoor air pollution (2014), p.85, available online at: http://documents1.worldbank.org/curated/en/701891468285328404/pdf/890650PUB0Clea00Box385269B00PUBLIC0.pdf
[100] Cleaning Pakistan's Air, Policy Options to address the cost of outdoor air pollution, (2014), p.178 available online at: http://documents1.worldbank.org/curated/en/701891468285328404/pdf/890650PUB0Clea00Box385269B00PUBLIC0.pdf
[101] Cleaning Pakistan's Air, Policy Options to address the cost of outdoor air pollution, 2014, p.125, available online at: http://documents1.worldbank.org/curated/en/701891468285328404/pdf/890650PUB0Clea00Box385269B00PUBLIC0.pdf

tightening them in line with Euro 5 or 6 is a recommended action to strengthen air quality management in Pakistan.[102] Pakistan's national air quality strategy is currently being reviewed and updated.

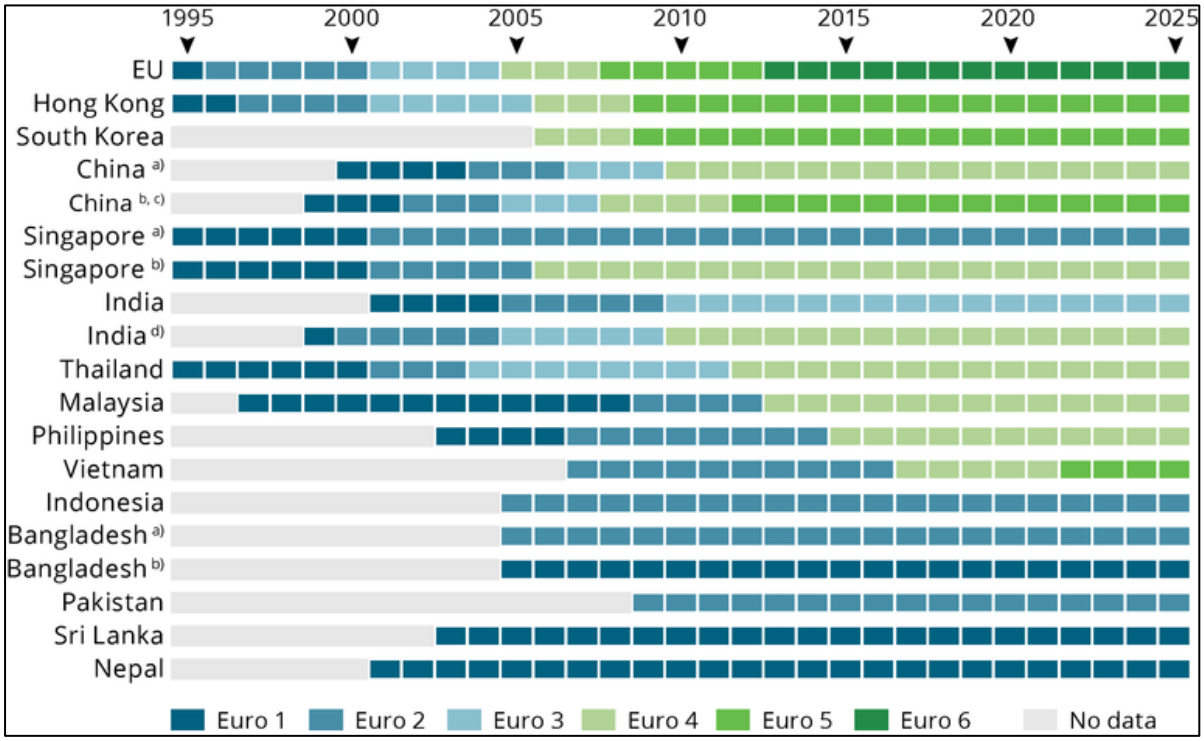
Dhaka, the capital of Bangladesh (and Bangladesh in general), has very low vehicle ownership, however the growth rate of ownership is quite high at around 8%.[103] Vehicle numbers are projected to continue rising under current circumstances. For this reason, stricter emissions standards which allow for improved enforcement of measures and retrofitting vehicles are seen as important steps to reduce pressure on air quality in Dhaka. This is conducted via emissions testing and monitoring. Emissions standards were introduced to Bangladesh in 1977, and were tightened to align with Euro 2/II in 2005. This is illustrated in Figure 6, which shows the year of (planned) adoption of the different EU Euro emission standards (Euro 1/I to Euro 5/V) for road vehicles, by various Asian countries.[104] Since there is not a local industry for vehicle manufacturing in Bangladesh, cars are largely imported from Japan, adopting their emissions standards but lagging behind by three to five years. Emissions standards can be performance- or technology-based, for instance implementing strict vehicle emissions standards or the compulsory use of catalytic converters. Several methods have been implemented in Dhaka, for example a ban on older vehicles and a differential tax based on the performance or age of the vehicle. However, these actions are limited by monitoring capacity (testing facilities for monitoring vehicle emissions during certification), poor institutional capacity, and enforcement. For existing vehicles in Dhaka, the proposed strategies to reduce pollution, relating to improved emissions standards, include:

- Strengthened vehicle inspection and maintenance;
- Enforcing the current ban on vehicles older than 20 years;
- Emissions based annual registration fees;
- Stringent emissions standards; and
- Emissions based import tariffs.[105]

Stringent emissions standards for all new and in-use imported vehicles is seen as likely to have a high impact and low cost. One co-benefit to enforcement of emissions standards is the public health benefit from the most polluting vehicles being kept off the roads. As noted above, the earliest emissions standards had more of a focus on GHGs such as CO_2, so there is also a benefit in being a climate change reduction measure. Although the set-up, running and quality control of emissions testing centres may seem like a lot of hassle and something that the general public may not like, this does create a number of jobs which could be beneficial to the local economy.

[102] Cleaning Pakistan's Air, Policy Options to address the cost of outdoor air pollution, 2014, p.178, available online at: http://documents1.worldbank.org/curated/en/701891468285328404/pdf/890650PUB0Clea00Box385269B00PUBLIC0.pdf
[103] Air Pollution Reduction Strategy for Bangladesh (2012), p.17, available online at: http://old.doe.gov.bd/publication_images/60_air_pollution__reduction_strategy.pdf
[104] Adoption of the EU Euro emissions standards for road vehicles in Asian countries, 2016, available online at: https://www.eea.europa.eu/data-and-maps/figures/number-of-international-environmental-agreements-adopted-1
[105] Air Pollution Reduction Strategy for Bangladesh (2012), p.43, available online at: http://old.doe.gov.bd/publication_images/60_air_pollution__reduction_strategy.pdf

Figure 6: The year of (planned) adoption of the different EU Euro emission standards (Euro 1/I to Euro 6/VI) for road vehicles, by various countries in Asia (last modified in 2016)[106]



4.1.3 Strict emissions standards and enforcement in public transport

As described in Section 4.1.2, emissions standards for vehicles are set in order to limit the amount of pollutants being released from a vehicle. Above the defined emission performance standard, other technologies are required to limit the vehicle emissions. This regulatory technique is particularly important in public transport because public transport vehicles travel almost constantly throughout the day, covering a significant number of kilometres compared to private vehicles. In addition, public transport vehicles are often more polluting than private cars – they are larger and tend to be powered by diesel fuel, and are heavier even before passengers are considered.

As with private cars, there are defined emissions standards for public transport type vehicles such as buses. It may be easier for cities to enforce these emissions standards in comparison to private vehicles, as the number of vehicles is likely to be a lot less and they tend to be owned by only a few companies within the city. Regular testing and quality control of the test centres is key to ensuring the public transport vehicles operating the city are operating to a suitable standard.

As outlined in Section 4.1.2, Zurich in Switzerland enforces pollutant limit values for CO, HC, NOx and particles (by mass and number).[107] These do not apply only to private vehicles, but also to public transport vehicles. Due to the stringent standards for passenger vehicles (Euro 5/V and 6/VI standards apply for passenger vehicles with diesel or direct-injection petrol engines), most public transport buses are equipped with particle filter systems as this is the only way to achieve the standard. Since 2008, the reimbursement of mineral oil tax to transport companies has been dependent on whether the buses are equipped with particle filters, which provides another incentive to install them. As with private vehicles, there are test cycles and durability requirements (over time periods and distances) for the emissions limit values, and these are checked periodically by the road traffic authorities (FEDRO) who enforce the emissions standards. There are also exhaust gas maintenance checks that vehicles must go through every two years unless they have an on-board diagnosis system. The ‘Ordinance on the technical

[106] Adoption of the EU Euro emissions standards for road vehicles in Asian countries, 2016, available online at: https://www.eea.europa.eu/data-and-maps/figures/number-of-international-environmental-agreements-adopted-1
[107] Emissions regulations for motor vehicles in Zurich, https://www.bafu.admin.ch/bafu/de/home/themen/luft/fachinformationen/massnahmen-zur-luftreinhaltung/massnahmen-zur-luftreinhaltung-beim-strassenverkehr.html

requirements for road vehicles' (VTS) regulates the criteria for classifying road vehicles, the registration test, inspection and exhaust maintenance of road vehicles, and the technical requirements for road vehicles.[108]

As mentioned in Section 4.1.1, Oxford (UK), is piloting a ZEZ from summer 2021.[109] The ZEZ plans include a requirement for all buses to be Euro 6/VI standard by December 2022, and to be zero-emission by 2035/37.[110] All Oxford-licensed black cabs (taxis) are also set to be zero-emission by 2025, with emissions standards being implemented in phases between 2020 – 2025 under the plan. All registered local buses and taxis, as well as any zero-emission vehicle, would not be charged in the ZEZ.[111] This supports the development and use of low emission local services, instead of private vehicles, since people are likely to choose to pay a smaller charge for low emission taxis and public transport rather than paying a ZEZ charge and then a parking charge for personal vehicles. Any vehicles driving or parking within the zone during charging hours would need to pay the required charge either before entering the zone, or by midnight the day after. Users would be able to pay through various methods, but it is anticipated that most people would pay online. This would be enforced using automatic number plate recognition (ANPR) and a penalty charge for those who do not pay on time.[112]

In Cambridge in the UK, a key theme within the local AQAP is to reduce emissions from buses and coaches. A target has been set for 100% of the current regular bus and coach fleet in Cambridge to be Euro VI or better (hybrid or electric), and all additional buses/coaches to be zero-emission capable. Buses can be retrofitted with low emission technology, which is supported by the Clean Vehicle Retrofit Accreditation Scheme (CVRAS, see Section 4.2.1).[113] The CVRAS uses a register of approved companies and emissions reduction systems to find which method of retrofit best suits a certain vehicle type. This is expected to lead to as much as a 33% reduction of total emissions in the central part of Cambridge. Within the AQAP, the importance of engaging with local bus operators through a Quality Bus Partnership (QBP)[114] is noted for successful implementation of this measure.[115]

As with emissions standards for private vehicles, a co-benefit to enforcement of emissions standards is the public health benefit from the most polluting vehicles being kept off the roads. Again, this is of particular importance for public transport vehicles as they often remain running while passengers embark and disembark (or queue to get on) so they are more exposed to the emissions than when using a private vehicle. There is also a benefit in being a climate change reduction measure. The set-up, running and quality control of emissions testing centres creates a number of jobs which could be beneficial to the local economy.

4.1.4 Strict emissions standards and enforcement in commercial vehicles

As described in Section 4.1.2, emissions standards for vehicles are set in order to limit the amount of pollutants being released from a vehicle. Above the defined emission performance standard, other technologies are required to limit the vehicle emissions. This regulatory technique is particularly important in commercial vehicles because these vehicles often travel a significant number of kilometres compared to private vehicles. In addition, commercial vehicles (especially heavy goods vehicles, HGVs) tend to be more polluting than private cars – they are larger, tend to be powered by diesel fuel, and are heavier even before any loads are considered.

[108] Ordinance on the technical requirements for road vehicles (VTS), Swiss Federal Council, 1995 (last updated May 2019), available online at: https://www.fedlex.admin.ch/eli/cc/1995/4425_4425_4425/de
[109] Oxford Low emission strategy, 2013, p.20, available online at: https://www.oxford.gov.uk/downloads/download/156/low_emission_strategy
[110] Oxford Zero Emission Zone, 2020, p.6, available online at: https://www.oxfordshire.gov.uk/sites/default/files/file/roads-and-transport-connecting-oxfordshire/ZEZ_update_Jan2020.pdf
[111] Oxford Zero Emission Zone, 2020, p.8, available online at: https://www.oxfordshire.gov.uk/sites/default/files/file/roads-and-transport-connecting-oxfordshire/ZEZ_update_Jan2020.pdf
[112] Oxford Zero Emission Zone, 2020, p.10, available online at: https://www.oxfordshire.gov.uk/sites/default/files/file/roads-and-transport-connecting-oxfordshire/ZEZ_update_Jan2020.pdf
[113] Clean Vehicle Retrofit Accreditation Scheme, 2021, available online at: https://energysavingtrust.org.uk/service/clean-vehicle-retrofit-accreditation-scheme/
[114] Three stages to better bus services using the Bus Services Act, 2018, p.20, available online at: https://bettertransport.org.uk/sites/default/files/pdfs/bus-services-act-guidance.pdf
[115] Cambridge City Council Air Quality Action Plan 2018 – 2023, 2019, p.51-78, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf

As with private cars, there are defined emissions standards for commercial type vehicles such as light goods vehicles (LGVs) and HGVs. It may be easier for cities to enforce these emissions standards in comparison to private vehicles, as the vehicles are likely to be part of a fleet that belong to a company. However, there may also be smaller businesses with just one or two vehicles that are easier to slip through the net. Regular testing and quality control of the test centres is key to ensuring the commercial vehicles travelling in and around the city are operating to a suitable standard.

As well as emissions standards for private vehicles and public transport vehicles, outlined in Section 4.1.2 and Section 4.1.3 respectively, Zurich in Switzerland also enforces pollutant limit values for commercial vehicles such as HGVs and other delivery vehicles.[116] There are stringent standards for commercial vehicles; Euro 5/V and 6/VI standards apply for vehicles with diesel or direct-injection petrol engines, as well as heavy commercial vehicles. Currently, the only way to comply with these standards is with the use of particle filters. Trucks with the lowest pollutant emissions available (Euro VI) are put into the most favourable tax category of the performance-based heavy vehicle tax (LSVA); this incentive is intended to further reduce particulate matter pollution. As with private and public transport vehicles, there are test cycles and durability requirements, as well as exhaust gas maintenance checks that vehicles must go through every two years, unless they have an on-board diagnosis system. The 'Ordinance on the technical requirements for road vehicles' (VTS)[117] regulates the criteria for classifying road vehicles, the registration test, inspection and exhaust maintenance of road vehicles, and the technical requirements for road vehicles, and FEDRO enforces the emissions standards. It is estimated that with closed particle filters, diesel soot in the exhaust gases can be reduced by up to 99%.

As well as setting emissions standards for private cars, the Swedish Transport Agency is responsible for regulations on LGVs, and HGVs (over 3.5 tonnes).[118] The emission classes are regulated by the Exhaust Gas Purification Act (2011: 318) for new vehicles registered from 1 May 2011. Older vehicles are classified in environmental class according to the repealed Act (2001: 1080) on motor vehicle exhaust purification and motor fuels. In both cases, the classification is linked to the EU regulations on exhaust emissions. The current exhaust emission requirements are based on exhaust gas testing according to European test methods. For LGVs, the entire vehicle is tested and approved in accordance with the methods and provisions of EU Regulation 715/2007; for HGVs, the engine is tested and approved according to methods and regulations in EU directive 2005/55/EC.

Kolkata, the capital of India's West Bengal state, is phasing out commercially driven vehicles which have been in use for 15 years or more in order to reduce vehicle emissions. The Transport Department issued an order restricting the use of older commercial vehicles like buses, taxis, and other commercial/transport vehicles within Kolkata Metropolitan Area (KMA) in 2012. The measure is implemented by the State Transport Authority (STA), West Bengal and all Regional Transport Authorities (RTAs) and all Registration Authorities falling within KMA. A total of 113,890 vehicles were phased out up to October 2018. This is conducted automatically through e-Vahan Software managed by National Informatics Centre (NIC), identifying vehicles in the database, and blocking transactions such as payment of taxes or renewal of permits. Enforcement has commenced and is an ongoing process. Commercial or transport vehicles and goods carriages with 15 years from the date of initial registration, are not allowed to re-register and are not allowed to enter Kolkata. This includes trucks, goods carriages, trailers, buses, and taxis. As with emissions standards measures for other types of vehicles, the implementation is limited by monitoring and enforcement capacity. Auto Emission Testing Centres (AETCs) are used to conduct pollution checks on vehicles, with 103 operational AETCs in Kolkata and Howrah cities and more being added. Additionally, holding of a valid PUC Certificate is mandatory for grant of 'Certificate of Fitness'. It is proposed that AETCs should be automated and connected to a centralized server to improve monitoring and enforcement.[119]

[116] Emissions regulations for motor vehicles in Zurich, https://www.bafu.admin.ch/bafu/de/home/themen/luft/fachinformationen/massnahmen-zur-luftreinhaltung/massnahmen-zur-luftreinhaltung-beim-strassenverkehr.html
[117] Ordinance on the technical requirements for road vehicles (VTS), Swiss Federal Council, 1995 (last updated May 2019), available online at: https://www.fedlex.admin.ch/eli/cc/1995/4425_4425_4425/de
[118] Exhaust regulations for motor vehicles in Sweden, https://transportstyrelsen.se/sv/vagtrafik/Miljo/Luftkvaliet-i-tatorter/Avgaser/
[119] Comprehensive Air Quality Action Plan for Kolkata (2018), p. 9-10, available online at: https://cpcb.nic.in/Actionplan/West%20Bengal.pdf

As with emissions standards for private and public transport vehicles, a co-benefit to enforcement of emissions standards is the public health benefit from the most polluting vehicles being kept off the roads. This is of particular importance for commercial vehicles as they tend to travel longer distances than private vehicles, and tend to be more polluting in general. There is also a benefit in being a climate change reduction measure. The set-up, running and quality control of emissions testing centres creates a number of jobs which could be beneficial to the local economy.

4.1.5 Anti-idling enforcement

Idling is the act of keeping a vehicle's engine running while stationary, for example whilst stuck in traffic or waiting to collect someone. Schools, hospitals, and bus stops are particular hotspots for idling, in that idling is more likely to occur at these locations, and sensitive age groups (such as children and older people) are more likely to be present there. Reduction in idling vehicles on the roads will contribute to a reduction in pollutant concentrations, including oxides of nitrogen (NOx), NO_2 and particulate matter.

There are a number of ways to implement anti-idling. The strictest approach is to employ specific officers to enforce anti-idling; these officers would patrol looking for idling vehicles and report / take note of the owner's and vehicle's details. The penalties for idling usually include fines that increase with each offence, or potentially driving bans. A warning could be given for the first offence, and the offender educated. Education and awareness campaigns about the impacts of idling vehicles should accompany any rules and regulations, as prevention can be just as effective, if not more effective, than fines.

The Singapore National Environment Agency (NEA) enforces strict anti-idling for all vehicles except a few exemptions (including vehicles where the engine is needed to be running for operation of on-board equipment (e.g. refrigerated trucks), moving vehicles in a queue, vehicles undergoing inspection or repair and enforcement/emergency vehicles).[120] Under the Environmental Protection and Management (Vehicular Emissions) Regulations[121] it is an offence for the driver of a motor vehicle to leave the engine of a vehicle idling while it is stationary, for reasons other than traffic conditions. As with adhering to vehicle standards in Singapore, owners can be fined up to $2,000 for their first offence and up to $5,000 for subsequent offences. It is not entirely clear how this is enforced by the NEA; however, members of the public are encouraged to report idling vehicles. Details that should be provided include the vehicle registration number, location, date, and time of the incident. Offences can be reported via an online feedback form,[122] or the MyENV mobile app. In addition to enforcement, the NEA regularly engages stakeholders to educate and remind their drivers to switch off the vehicle engines when stationary. Authorised vehicle inspection centres (such as VICOM, JIC Inspection Services and STA Inspection) are provided with educational pamphlets[123] to remind motorists that it is an offence to idle while stationary.

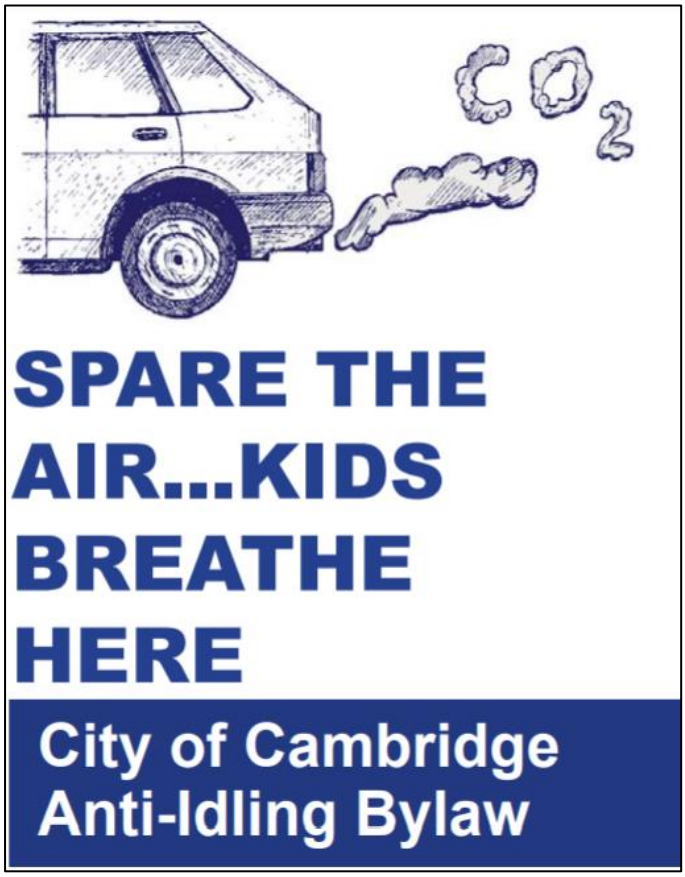
In Cambridge (UK) under by-law 212-15,[124] implemented in 2015, drivers are not allowed to park and allow a vehicle to idle for more than one minute within designated areas (including highways, drop-off zones, and parking lots around schools, libraries, arenas, pools, recreation centres and parks).[125] This requires enforcement by local authorities. A public consultation in Cambridge showed that some respondents would like the city council to enforce idling offences, especially near schools, highlighted in the images used in an awareness-raising brochure shown in Figure 7. More than half the respondents (64%) replied yes to the question 'Does traffic idling affect you?'. Cambridge's AQAP contains actions toward anti-idling enforcement, implemented through a publicity campaign, penalty notices for non-compliance and a review of traffic signals in the city. The cost of a penalty ticket is currently between

[120] Air Pollution Regulations in Singapore, https://www.nea.gov.sg/our-services/pollution-control/air-pollution/air-pollution-regulations
[121] Environmental Protection and Management (Vehicular Emissions) Regulations for Singapore (last updated in January 2021), available online at: https://sso.agc.gov.sg/SL/EPMA1999-RG6?DocDate=20120629&ViewType=Pdf&_=20200723162422
[122] Singapore National Environment Agency Feedback / Enquiry form, https://www.nea.gov.sg/corporate-function/feedback
[123] Singapore National Environment Agency pamphlet on anti-idling, available online at: https://www.nea.gov.sg/docs/default-source/our-services/pollution-control/air-pollution-regulations/idling-engine-pamphlet-newe5472ee768404dbd9080d0f33cde1563.pdf
[124] BY-LAW 212-15 of the corporation of the city of Cambridge, 2015, p. 3-4, available online at: https://www.cambridge.ca/Modules/Bylaws/Bylaw/Download/938e268c-62ff-4734-8f87-c412a123305e
[125] BY-LAW 212-15 of the corporation of the city of Cambridge, 2015, p. 3-4, available online at: https://www.cambridge.ca/Modules/Bylaws/Bylaw/Download/938e268c-62ff-4734-8f87-c412a123305e

£50 - £70 (approximately INR 5,000 – INR 7,000).[126] This measure would require additional resources for enforcement and potentially additional by-laws for effective implementation.[127]

Although there is debate on how much of an impact reduction in idling vehicles has on air pollution levels, a major co-benefit is reduction in fuel wastage. Vehicle owners using less fuel will save money, as well as potentially reducing the impacts of climate change. By idling, vehicle owners are putting themselves in a situation where they are exposed to high levels of pollution from their own vehicle, therefore, the greatest health benefits of anti-idling potentially come to the idlers themselves.

Figure 7: Anti-idling campaign image advertising the updated by-law 212-15[128]



4.1.6 Smoky vehicle enforcement

Vehicle smoke is a major source of smoke in urban areas. Well-maintained vehicles should produce very little smoke from exhausts, except when they are starting up, accelerating hard or climbing steep hills. However, some vehicles emit dense plumes of smoke which contains air pollutants, especially particulate matter. Excessive smoke may be caused by poor maintenance of the vehicle or a technical problem which has arisen since the vehicle's last service or inspection. Removal of smoky vehicles from the roads will contribute to a reduction in particulate matter concentrations.

As with anti-idling, there are a number of ways to reduce smoky vehicles. The strictest approach is to employ officers to report smoky vehicles and issue fines. A warning could be given for the first offence, and the offender educated. Education and awareness campaigns about the impacts of smoky vehicles, as well as how to care for a vehicle to prevent it from becoming smoky, should accompany any rules and regulations.

[126] Parking tickets and appeals, Cambridge, https://www.cambridgeshire.gov.uk/residents/travel-roads-and-parking/parking-permits-and-fines/parking-tickets-and-appeals
[127] Cambridge City Council Air Quality Action Plan 2018 – 2023, 2019, p.96, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf
[128] Anti-Idling Brochure, 2015, available online at: https://www.cambridge.ca/en/learn-about/resources/Anti-IdlingBrochure2016-AODA2.pdf

The Singapore National Environment Agency (NEA) takes strict action against all types of smoky vehicles on the roads.[129] Under the Environmental Protection and Management (Vehicular Emissions) Regulations[130] it is an offence for any vehicle to emit smoke while on the road. No exceptions are listed, and owners can be fined up to S$2,000 (approximately INR 109,000) for their first offence and up to S$5,000 (approximately INR 273,000) for subsequent offences. If identified, owners of smoky vehicles are required to send their vehicles for smoke emission inspection at an authorised vehicle inspection centre; the owner will be fined if the vehicle fails the inspection. The owner is then required to rectify and send their vehicle for re-inspection which they must pass before the vehicle will be allowed on the road. It is not entirely clear how this is enforced by the NEA, however as with idling vehicles, members of the public are encouraged to report smoky vehicles to the NEA; details that should be provided include the vehicle registration number, location, date, and time of the incident. Offences can be reported via an online feedback form,[131] or the MyENV mobile app. In addition to enforcement, the NEA provides some helpful tips online as to how to take care of vehicles to reduce the chance of them emitting smoke.

Particulate matter is a key pollutant in smoke; these particles can cause health problems, especially in asthma sufferers and those with other respiratory issues. A reduction in smoky vehicles would be likely to benefit these groups of people the most. Smoke from vehicles (or any other source) can also leave dirt on properties, particularly white surfaces such as windows. It may even cause a smog to be visible in the air, although this is only really experienced in very high pollutant concentrations and is likely to be from a number of sources rather than just smoky vehicles. Therefore, a reduction in smoke from vehicles can also improve the visible environment.

4.1.7 Enhanced street cleaning

As particulate matter has been identified as a significant issue in Bhubaneswar and Cuttack, key actions outlined in the CAAPs relating to reducing road dust include the phase-in of street sweeping and cleaning. This has been described in the comprehensive clean air action plan for Bhubaneswar as “periodic mechanized sweeping on roads particularly in roads with heavy traffic and water sprinkling every two days”.[132] While road cleaning can help to reduce PM concentrations, this measure should be used alongside street design guidelines for paving of roads with vegetative barriers, which would reduce ambient concentrations of PM, other actions included in the CAAP for Cuttack.[133]

Dust deposited on roads may be of natural origin (e.g. inflow from the Sahara or other locations, sea salt, pollen from trees) or anthropogenic (such as the wearing of tyres or the road surface, brake linings and road markings, the dry and wet deposition of industrial or municipal dust, and winter road maintenance agents). Non-exhaust PM deposited on the road surface can then become suspended (or re-suspended) in the air through the action of vehicle tyres, vehicle induced turbulence, and wind. As exhaust emissions decline as a result of increasingly stringent limits, the relative importance of non-exhaust emissions will grow.[134] There are a number of factors that are likely to affect non-exhaust emissions, including driving speed, frequency and severity of braking, traffic volume and composition, type of brake liner, road surface materials, and meteorological factors such as temperature, humidity, rainfall, and wind conditions. Street cleaning comprises of the sweeping and washing of street surfaces and flushing is the term often used to describe the spraying of high pressure water onto the road surface to wash dust into the drains – this can include washing footpaths as well.

In the Nordic countries (Denmark, Finland, Norway, and Sweden) street cleaning has been used to mitigate PM emissions, although this is said to be most effective when combined with active dust binding (see Section 4.3.6). In Helsinki in Finland, a “street scrubber” combining high pressure flushing of the

[129] Air Pollution Regulations in Singapore, https://www.nea.gov.sg/our-services/pollution-control/air-pollution/air-pollution-regulations
[130] Environmental Protection and Management (Vehicular Emissions) Regulations for Singapore (last updated in January 2021), available online at: https://sso.agc.gov.sg/SL/EPMA1999-RG6?DocDate=20120629&ViewType=Pdf&_=20200723162422
[131] Singapore National Environment Agency Feedback / Enquiry form, https://www.nea.gov.sg/corporate-function/feedback
[132] Comprehensive action plan for clean air for non-attainment cities of Odisha – Bhubaneswar, 2018.
[133] Comprehensive action plan for clean air for non-attainment cities of Odisha – Cuttack, 2018.
[134] Review of Impact of Street Cleaning on PM10 and PM2.5 Concentrations in Northern and Central Europe, AIRUSE, 2016, available online at: http://airuse.eu/wp-content/uploads/2013/11/R15_AIRUSE-Street-cleaning-CNE.pdf

pavement surface with immediate vacuuming of the washing liquids has been shown to be effective in reducing PM_{10} suspension in conditions with high road surface dust.[135] An EV street sweeper is to be piloted in the city during 2021, developed by Finnish street maintenance technology developer Trombia Technologies.[136] The battery-powered street sweeper reportedly uses less than 15% of the power required for currently available heavy suction sweeping technologies, meaning the new development could help realise the potential for mass-electrification and carbon-neutralisation of one of the heaviest vehicle technologies in use in cities. Final product pricing will be available to Norwegian and German markets during summer 2021, with mass-starting deliveries commencing in early 2022.

Some modern sweeper techniques have been shown to reduce road dust and ambient PM_{10} concentrations in the short term. Dry vacuum sweeping has been implemented in Stockholm, the capital of Sweden. Dry vacuum cleaning, with very a high vacuum, has been shown to reduce the local contribution to PM_{10} by approximately 20%.[137] Tests in Norway have shown that high-pressure water washing, in combination with strong vacuum cleaning, is efficient to remove road dust load. The same tests in Norway showed that a lower cleaning speed also enhanced the reduction in dust load.

Other impacts of road dust particles are reduced visibility, corrosion, and the nuisance caused by dust on surfaces (e.g. windows and cars) – all of these impacts can be mitigated by various combinations of street cleaning techniques.

4.1.8 Road and path improvements / maintenance

Optimised pavement properties have been shown to reduce both exhaust and non-exhaust emissions of PM, as has maintenance of roads and footpaths. Maintained roads will enable smoother driving behaviours, which in turn reduce pollutant emissions from the exhaust, as well as PM emissions from friction between brake plates or between tyres and the road. Maintenance of roads also minimises the amount of deposited dust on the road that can be suspended (or re-suspended).

Optimisation of pavement properties can be achieved by construction using larger stone sizes and durable rock aggregates, which increase wear resistance and so reduce the amount of PM emitted from the roads. In countries where sanding or salting is required in winter, restricting the amount of sand used or replacing it with salt is an option. If sand must be used, washed, sieved sand is the best type. Studded tyres are also known to cause PM emissions from roads, so in countries where these are use methods to reduce their use (to only when necessary) such as taxes, seasonal restrictions or complete bans should be considered.

The examples of best practice relating to road and path improvements and maintenance in Europe are found in the Nordic countries: Finland, Denmark, Norway, and Sweden. However, the weather and climatic conditions in Europe, and especially in these countries, are very different to the conditions in India. Therefore, the challenges faced by these case study cities will also vary from the challenges faced by Cuttack and Bhubaneswar. The principles from these examples of best practice can still be utilised by the Indian cities, but the differences must be considered.

In Copenhagen, Denmark, a section of a busy motorway leading in and out of the city was chosen as the test site for a special climate-friendly asphalt, as part of the development of pavements that reduce emissions from road traffic.[138] The material is reported to be the only of its kind in the world and has been installed in a 500 metre long section of the motorway; it will be monitored closely over a number of years for rolling resistance, durability and safety. The asphalt was to be installed on 50 km throughout the country during 2018. The goal of the asphalt is to reduce the 'rolling resistance' (resistance between tyres and the road surface) – reducing the amount of fuel vehicles will use. Lowering the rolling resistance by up to 4%, would save about 57 million litres of fuel by 2035 upon full implementation, according to a specialist at the Danish Road Directorate. The anticipated benefit-cost ratio is 40 to 1;

[135] Road dust and PM10 in the Nordic countries, Measures to reduce road dust emissions from traffic, Nordic Council of Ministers, 2017, available online at: https://norden.diva-portal.org/smash/get/diva2:1069152/FULLTEXT02.pdf
[136] Helsinki pilots world's first high-power autonomous street sweeper, https://www.cittimagazine.co.uk/videos/helsinki-pilots-worlds-first-high-power-autonomous-street-sweeper.html
[137] Road dust and PM10 in the Nordic countries, Measures to reduce road dust emissions from traffic, Nordic Council of Ministers, 2017, available online at: https://norden.diva-portal.org/smash/get/diva2:1069152/FULLTEXT02.pdf
[138] The Danish Road Directorate is testing climate-friendly asphalt, https://www.worldhighways.com/wh3/news/danish-road-directorate-testing-climate-friendly-asphalt

for each DKK 1 million (Danish Krone, approximately INR 12 million) invested will save DKK 40 million (approximately INR 473 million) in fuel. The sponsoring parties behind the research and the deployment include the Danish Innovation Fund, and the Danish Energy and Climate Ministry.

The city of Stockholm, capital of Sweden, has implemented a measure to reduce PM emissions that does not involve direct maintenance of the roads, but rather indirectly preserves road quality by limiting the interaction between the road surface and tyres.[139] Studded tyres are used in Sweden in the winter months, to give better grip in icy conditions. Such conditions may not be applicable to Cuttack and Bhubaneswar, but the principle remains the same – reducing the interaction between the road surface and a vehicle's tyres will reduce the emissions of PM. The Swedish Transport Agency has set a limit on the number of studs that are allowed on each tyre (as of 2013), therefore reducing the interaction between tyre and road.

Keeping well-maintained roads will reduce fuel usage and cut costs for drivers, while lowering CO_2 and other GHG emissions. Creating roads of a high standard to begin with, will lower the requirement for road maintenance and save additional funds.

4.1.9 Sprinkling water at junctions

A water spray can be used to provide a short-term suppression of road dust, as the moisture from the spray causes dust to stick together, thereby reducing PM in the air. This can be effective for hours or days, depending on the traffic and weather conditions in the area.

Sprinkling, as pictured in Figure 8, is conducted using water trucks which sprinkle water on the roads at regular intervals, depending on the capabilities and requirements of the area. Regular, light watering is reported to be more effective than frequent, heavy watering.[140] Water is a cheaper and safer option than other chemical-based dust reduction sprays, as the run-off is harmless to the environment. However, it is less effective than chemical dust-binding, the effects of which can last for much longer[141] (see section 4.3.6).

Figure 8: East Delhi Municipal Corporation (EDMC) tankers spraying water on roads in New Delhi. Photo by Asian News International[142]

[139] The Swedish Transport Agency's work with air quality, https://transportstyrelsen.se/sv/vagtrafik/Miljo/Luftkvaliet-i-tatorter/
[140] Top Ten Dust Control Techniques List (2021), available online at: https://dec.alaska.gov/air/anpms/dust/control-techniques-list
[141] Evaluating Costs of Dust Palliatives for Rural Communities (2021), available online at: https://dec.alaska.gov/air/anpms/dust/palliatives/
[142] EDMC sprinkles water on roads to reduce dust, firecracker pollution in Delhi, 2019, available online at: https://www.hindustantimes.com/delhi-news/edmc-sprinkles-water-on-roads-to-reduce-dust-firecracker-pollution-in-delhi/story-QNiPErrxdikZf3HWNeEC1K.html

Sprinkling of water daily at important traffic junctions is used in Kolkata, India during the peak winter months (October to February). Kolkata Municipal Corporation (KMC) has implemented this to mitigate suspension of PM in the air. KMC applies sprinkling of water at busy junctions and on small trees and shrubs planted at road dividers and roadside gardens, in order to stabilise dust and soil on the road and at the roadside. The West Bengal Pollution Control Board (WBPCB) is providing funding for ten water sprinkling vehicles for KMC. A target to improve this action is to use recycled water, so as not to compromise other water requirements.[143]

Co-benefits of water sprinkling include health benefits from fewer particulates in the air, as well as better visibility, which can reduce incidence of road accidents.[144]

4.1.10 Scrappage of two-stroke three-wheelers

Motorcycles and three-wheelers dominate the vehicle fleet in India, providing crucial delivery, personal mobility, and public transport services. However, these vehicle types are some of the most polluting, running on diesel and suffering from incomplete and inefficient combustion. According to the CAAP for Cuttack, under the current emissions standards of BSIV, a diesel auto is legally allowed to emit 1.7 times higher PM and 1.3 times higher NOx and HC than a BSIV diesel car.[145] The gap between autos and diesel cars will further widen under BSVI regulations. Even after meeting BSVI emissions standards, a diesel three-wheeler will emit close to six times higher PM and two times more NOx compared to a BSVI diesel car. Therefore, emissions standards alone are not enough to mitigate the polluting impact of two-stroke three-wheelers.

Retrofitting and scrapping of old vehicles are recommended measures to reduce emissions and improve fuel efficiency. This relies on financial incentives and access to replacement vehicles with more sustainable fuels such as compressed natural gas (CNG) or electric batteries. Scrapping older vehicles has benefits for fuel efficiency, with lower maintenance and fuel costs for newer vehicles.

Two-stroke gasoline engine three-wheelers (small taxis and rickshaws) and two-wheelers (motorbikes and scooters) are a significant source of PM emissions and represent a large proportion of the vehicle fleet in many Asian cities.[146] For example, in 2014, motorcycles, scooters and rickshaws represented 22% of traffic volume in Kolkata, India.[147] A proposed measure within the CAAP for Kolkata is to operationalise E-Rickshaws and E-Carts as the mode of transport for last mile connectivity. This could reduce vehicular emissions through introduction of electric two-wheelers and para-transits (three-wheelers and taxis), along with infrastructure for charging and battery disposal. Priority may be given to electric para-transit vehicles for last mile connectivity in central pedestrianised areas, reducing congestion. In order for this to take place, a fiscal strategy is required to promote electric mobility. So far under this measure, all three-wheelers operating in Kolkata City are now four-stroke liquefied petroleum gas (LPG) autos (which fall within category of green vehicles).[148]

Two-stroke three-wheelers were also identified as a major source of PM in Dhaka, Bangladesh, due to incomplete and inefficient combustion in this type of vehicle. This led to a measure to phase out two stroke three-wheelers from January 1, 2003. A replacement scheme took place, switching from two-stroke three-wheeler taxis to new four-stroke CNG taxis, imported from India. Around 12,000 existing two-stroke ‘baby taxis’ were replaced by 9,000 new CNG taxis in Dhaka city, ensuring a minimum level of demand for CNG fuel. A significant reduction in PM pollution was achieved with this measure, measured at the Department of Environment’s (DoE) Continuous Air Monitoring Stations (CAMS). This policy had public support, due to the installation of mandatory meters to control travel fares in the new CNG three-wheelers and taxis, avoiding additional costs for travellers as an outcome of the measure.

[143] Comprehensive Air Quality Action Plan for Kolkata (2018), p. 21, available online at: https://cpcb.nic.in/Actionplan/West%20Bengal.pdf
[144] Dust Control (n.d.), available online at: https://megamanual.geosyntec.com/npsmanual/dustcontrol.aspx
[145] Comprehensive action plan for clean air for non-attainment cities of Odisha – Cuttack, 2018.
[146] Two- and three wheelers Sustainable transport: A sourcebook for policy-makers in developing cities (2002) p.7 http://sutp.transport-nama.org/files/contents/documents/resources/A_Sourcebook/SB4_Vehicles-and-Fuels/GIZ_SUTP_SB4c_Two-%20and%20Three-Wheelers_EN.pdf
[147] Comprehensive Air Quality Action Plan for Kolkata (2018), p. 8, available online at: https://cpcb.nic.in/Actionplan/West%20Bengal.pdf
[148] Comprehensive Air Quality Action Plan for Kolkata (2018), p. 23-2, available online at: https://cpcb.nic.in/Actionplan/West%20Bengal.pdf

The banned two-stroke three-wheeler taxis were also allowed to work in other areas of Bangladesh, so that protests over loss of income from the measure were minimised. Both of these aspects aided the successful implementation of the measure. An additional economic benefit from the policy included reduced fuel (petroleum) import bills, as natural gas is an indigenous resource to Bangladesh.[149]

In Jakarta, the capital of Indonesia, vehicle ownership is rising rapidly and expected to rise from 57 million registered vehicles in 2007 to 93 million in 2030. Two-wheelers are growing fastest in number, with motorcycles representing 74.8% of the vehicle fleet in 2010. A scrappage programme for old two-stroke three-wheelers (bajaj) was initiated by the city government of Jakarta. To ensure the phase-out of old bajaj, the government only issues licenses for new vehicles. This measure is conducted in collaboration with the bajaj operators association and Bajaj Auto Ltd., which sell CNG bajajs on credit financing schemes to owners. A key barrier to progress with the scheme is a taxation system in the city which does not favour CNG, meaning slow progress. More than 500 out-dated two-stroke three-wheelers of the 14,000 targeted in Jakarta have been scrapped and replaced by new CNG three-wheelers. However, upgrading of old bajaj to CNG-powered ones has been slow.[150]

Scrappage of two-stroke three-wheelers leads to reduced air pollution, but also to reduced GHG emissions from the vehicles, with benefits for the health of the local population.[151] For bajaj owners, the conversion gives other benefits including low fuel and maintenance costs, enabling a higher return.

[149] Air Pollution Reduction Strategy for Bangladesh (2012), pp.35 – 37, available online at: http://old.doe.gov.bd/publication_images/60_air_pollution__reduction_strategy.pdf
[150] Indonesia air quality profile (2010), p.20, available online at: http://www.indiaenvironmentportal.org.in/files/Indonesia_Air_Quality_Profile_-_2010_Edition.pdf
[151] A Technical Assessment of Emissions and Fuel Consumption Reduction Potential from Two and Three Wheelers in India (2012), p. 92-93, available online at: https://theicct.org/sites/default/files/publications/Iyer_two-three-wheelers_India_August2012.pdf

4.1.11 Evaluation of direct emission control measures

The direct emission control measures described above have been evaluated according to the criteria outlined in Section 4. Table 1 provides a summary of the results.

Table 1: Evaluation of direct emission control measures

Measure	Evaluation according to criteria						
	Which pollutants are impacted?	Air quality impact (1-5)	Costs (1-5)	Co-benefits (1-5)	Reliance on other measures (1-5)	Innovation (1-5)	Prospective timescale (1-5)
Driving bans / LEZs	**NOx, PM**	✓✓✓✓✓	✓	✓✓✓	✓✓✓✓	✓✓✓✓	✓✓✓
Emissions standards for private vehicles	**NOx, PM**	✓✓✓	✓	✓	✓✓✓✓✓	✓✓✓	✓✓
Emissions standards for public transport	**NOx, PM, SO_2**	✓✓	✓	✓✓	✓✓	✓✓✓	✓✓
Emissions standards for commercial vehicles	**NOx PM SO_2**	✓✓✓	✓	✓	✓✓✓✓✓	✓✓✓	✓✓
Anti-idling enforcement	**NOx, PM**	✓✓	✓✓	✓✓	✓✓✓✓✓	✓✓	✓✓✓✓
Smoky vehicle enforcement	**PM**	✓✓	✓✓	✓✓✓	✓✓✓✓✓	✓✓	✓✓✓✓
Enhanced street cleaning	**PM**	✓✓	✓✓✓✓	✓✓✓✓	✓✓✓✓	✓	✓✓✓✓✓
Road / path improvements & maintenance	**PM**	✓✓	✓✓	✓✓✓✓	✓✓	✓	✓✓✓
Sprinkling water at junctions	**PM**	✓	✓✓✓	✓✓✓	✓✓✓✓✓	✓	✓✓✓✓✓
Scrappage of 2-stroke 3-wheelers	**NOx, PM**	✓✓✓	✓	✓	✓✓✓✓✓	✓✓	✓✓✓

4.2 Fuel switching

4.2.1 Low-emission bus fleets including retrofitting

Switching to zero-emission (electric) buses is not the only option when upgrading diesel bus fleets. It may not be realistic for a city to purchase a new fleet of electric buses, in which case cheaper options such as Euro VI buses, hybrids, or even retrofitting older buses will all contribute to a reduction in pollutant emissions. It is important that bus fleets are as clean as possible, because public transport vehicles travel significantly greater distances daily than private vehicles.

There are two ways to ensure bus fleets switch to cleaner vehicles. A higher standard of vehicle can be made a requirement to operate in the city, or, incentives can be provided to upgrade buses. A combination of both methods is likely to be the most successful. Requirements to operate in the city may cover a certain part of the city (e.g. the centre, which is likely to be the most polluted) and be similar to a driving ban or LEZ (see Section 4.1.1). Incentives to upgrade buses may include grants to purchase new vehicles of a higher standard, help with retrofitting, exemption from taxes / charges, or other benefits as outlined in Section 4.2.3.

In November 2018, the European Commission approved €107 million of support for the retrofitting of diesel buses in Germany.[152] The measure aims contribute to reduction in NOx emissions of over 2,000 tonnes per year, while limiting distortions of competition. The funding will support the retrofitting of diesel public passenger transport buses in approximately 90 municipalities where the limits for NOx emissions were exceeded in 2016 and/or 2017. The support will cover the costs of the retrofitting systems and their installation and is part of the German Federal Government's "Immediate Clean Air Programme for 2017-2020" (Sofortprogramm Saubere Luft 2017-2020). The retrofitting is expected to cut NOx emissions of each bus by at least 85%. The planned support for the retrofitting of up to 7,000 diesel buses is expected to lead to a reduction of an estimated 2,200 tonnes of NOx per year.

The city of Reutlingen in Germany, in their 2018 “Master plan for the design more sustainable and emission-free mobility”[153], as well as replacing some diesel buses with electric buses also plans to replace older buses with Euro VI buses, or retrofit. Although this would not achieve as great an emissions reduction as replacement with electric buses, it can be a more cost-effective option in the lesser polluted areas, or on routes that don’t run as frequently. The air quality plan for Reutlingen states that replacement of a Euro V bus with a Euro VI bus can lead to a specific NOx emission reduction of up to 95% in real operation, and estimated this measure would reduce the measured NOx concentration by 1.7 $\mu g/m^3$ on the main road in the centre of Reutlingen. The city has approximately 100 buses in use, and expected to receive funding to cover 40% - 60% of the upgrade costs (up to €15,000 (approximately IND 1.3 million) per bus, from the European Commission fund).

In Cambridge (UK), source apportionment shows that traffic emissions are the main source of air pollution in the city, largely attributed to buses in the city centre and cars elsewhere. A key objective of the previous Cambridge AQAP (2008) was to reduce emissions from buses and taxis by requiring newer vehicles with higher Euro emission standards, however, the expected improvement in air quality has not yet been observed. This may be due to an underestimation of the impact of HGVs on emissions. The updated AQAP (2018) includes a Strategic Bus Review to outline potential options for improving the bus services in the short, medium, and long term. The Strategic Bus Review aims to improve public transport offered in Cambridge, further reducing the need to travel by private vehicle.[154] The Cambridge Transport Strategy, laid out in the most recent AQAP, also aims to improve the bus service by substituting current buses with other modes of transport (‘greener’ alternatives), so the Greater Cambridge Partnership (GCP) has commissioned a feasibility study into the provision of electric / hybrid public transport options.[155] Retrofitting of vehicles is supported by the Clean Vehicle Retrofit

[152] State aid: Commission approves €107 million public support for greener buses in Germany, https://ec.europa.eu/commission/presscorner/detail/en/IP_18_6414
[153] Master plan for the design more sustainable and emission-free mobility, Green City Plan Reutlingen, 2018, available online at: https://www.reutlingen.de/de/Rathaus/Rathaus-Themen/Verkehr-und-Mobilitaet/Green-City
[154] Cambridge City Council Air Quality Action Plan 2018 – 2023, 2019, p.54, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf
[155] Cambridge City Council Air Quality Action Plan 2018 – 2023, 2019, p.26, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf

Accreditation Scheme (CVRAS), which uses a tool to recommend the best retrofit companies and technologies based on vehicle type.[156] For instance, exhaust after-treatment systems combining diesel particulate filter (DPF) and selective catalytic reduction (SCR) technology are the most widely applied for, for buses.[157]

In Oxford, also in the UK, the success of the bus LEZ (see Section 4.1.1) was largely assisted by government support for cleaner buses. The Department for Transport (DfT) launched the Clean Bus Technology Fund in 2015; local councils were able to apply for grants up to £500,000 (approximately IND 49.7 million) to upgrade buses with technology to reduce emissions in areas of poor air quality.[158] Since then, the funding has increased and the amount that councils can apply for has also increased. Between 2017 – 2019, Oxford City Council received over £1.6 million (approximately IND 159 million) in funding, allowing for 83 buses to be retrofitted.[159] In total, from 2017 – 2019, the Clean Bus Technology Fund awarded nearly £40 million in funding to 20 local authorities, to retrofit over 2,700 buses in the UK. The main focus of the retrofitting is to reduce tailpipe emissions of NO_2, but particulate matter emissions are also reduced by many retrofitting options as well. According to the CVRAS (see the previous case study for Cambridge), common retrofitting technologies include SCR (fitted to exhaust systems), hybrid powertrain systems, and re-powering engines with gas (LPG or CNG). As demonstrated in Oxford by the bus-based LEZ, retrofitting and grants to enable local governments to pursue this are extremely useful, alongside upgrading some vehicles to EVs.

A major co-benefit of retrofitting bus fleets is that the existing fleet does not have to be scrapped. For the city, retrofitting is potentially much more financially accessible than purchasing a fleet of electric buses.

4.2.2 Upgrade taxis including retrofitting and licensing conditions

Where vehicle upgrades are concerned, the greatest improvements in air quality are likely to come from upgrading the vehicles with the highest daily mileage. For example, replacement of a diesel taxi that travels all day every day with a cleaner vehicle (such as a higher Euro standard, a petrol vehicle or hybrid), will remove more emissions from the roads than replacement of one diesel private vehicle that makes fewer, shorter trips per day. Although EV taxis are the ideal replacement for diesel taxis, it may not be feasible for a taxi company or operator to replace their vehicle(s) with EV(s).

Licensing conditions can be used to encourage taxi companies operating in a city to upgrade their taxis to a higher Euro standard. Many UK cities have updated their taxi licensing conditions for this reason. However, incentives should also be considered rather than just ‘hard’ measures. Taxis of a higher Euro standard, or EVs or hybrids, may have access to designated taxi ranks in more desirable locations in the city where they will attract the most business. There are the options of tax incentives for cleaner vehicles, and grants for retrofitting and/or upgrades (see Section 4.2.3 for other incentives for cleaner vehicles).

In Cambridge (UK), the current AQAP includes measures to reduce emissions from taxis, with a target of a 30% electric or petrol hybrid taxi fleet by 2023, increasing to 100% of the fleet by 2028. Annual uptake targets have been set by the Office for Low Emission Vehicles (OLEV), with progress updated in the Annual Status Report (ASR).[160] The ASR is an annual requirement to demonstrate the strategies employed by Cambridge City Council to improve air quality and any progress that has been made, including ambient pollutant concentrations. The installation of taxi-only rapid charge points is expected to cost £626,000 (approximately IND 63 million), on top of the cost of fee reductions over five years to incentivise low and ultra-low emission taxi uptake. There are currently eight charge points specifically for local taxis, with plans to install 16 more by 2021. The implementation of a CAZ is also expected to

[156] Clean Vehicle Retrofit Accreditation Scheme, 2021, https://energysavingtrust.org.uk/service/clean-vehicle-retrofit-accreditation-scheme/
[157] Clean Vehicle Retrofit Accreditation Scheme, 2021, https://energysavingtrust.org.uk/service/clean-vehicle-retrofit-accreditation-scheme/
[158] Clean Bus Technology Fund, https://www.gov.uk/government/collections/clean-bus-technology-fund
[159] Government funding boost for bus industry in drive to improve air quality, https://www.gov.uk/government/news/government-funding-boost-for-bus-industry-in-drive-to-improve-air-quality
[160] 2019 Air Quality Annual Status Report, Cambridge, 2019, available online at: https://www.cambridge.gov.uk/media/7417/air-quality-annual-status-report-2019.pdf

encourage the uptake of low emission vehicles, which would be exempt from fees. It is expected that this measure will lead to a 20% - 30% reduction in emissions from taxis.[161]

As Uber, a Private Hire Vehicle (PHV) service, has expanded across Europe, there has been concern that the increase in registered PHVs has increased the number of diesel-powered trips in many European cities.[162] Historically, the number of taxis in European cities was limited due to the licensing system, however, Uber has changed the PHV sector and tens of thousands of partner drivers who offer passengers rides through the app in large urban areas are now registered. A broad coalition of green Non-Government Organisations (NGOs) in the USA, Germany, France, UK, Netherlands, and Belgium launched the #TrueCostOfUber campaign in November 2019.[163] The collective action aims to force Uber to clean up its act in order to operate in cities across Europe and the US. The company has managed to help their drivers switch to zero-emission cars in London thanks to the ultra-low emission zone (ULEZ). The #TrueCostOfUber campaign therefore calls on Uber to go 100% clean in large cities by 2025.

One possible co-benefit of this measure is increased publicity and therefore business for local taxi companies. Some users may choose a low emission taxi for their journey over a traditional taxi because of their environmental beliefs. As any rules, schemes, and incentives for upgrading taxis need to be well publicised, this in turn could provide increased publicity for the taxi owners and/or companies that have taken advantage of the schemes.

4.2.3 Incentives for cleaner vehicles

This measure relies on the assumption that providing incentives or benefits for cleaner vehicles (such as Euro 6/VI, hybrids, or EVs) will encourage more people to switch to these cleaner vehicles sooner than they may have otherwise. This measure often works well in combination with 'hard' measures such as driving bans, or can provide an alternative to harder measures.

There are a wide range of incentives that could be considered:

- Preferential parking policies to reduce costs for electric vehicles (also in association with EV chargers & associated costs);
- Priority traffic management measures for ultra-low emission vehicles (ULEVs) (e.g. bus lane use);
- Exemptions from LEZ charges and congestion charges;
- Tax incentives for low emission vehicles; and
- Early upgrade schemes.

Different incentives will be appropriate for different cities, depending on the powers available to the local government, the amount of funding available, and the current EV infrastructure. A combination of incentives is likely to be the most effective way to increase uptake of cleaner vehicles.

The Singapore NEA runs a Vehicle Emission Scheme (VES) as well as an Early Turnover Scheme (ETS), both of which encourage purchase of cleaner vehicles, by granting rebates or imposing surcharges based on how clean the vehicle's emissions are.[164] The VES commenced on 1st January 2018 and ran until the end of 2020; purchase of a cleaner vehicle allows for a minimal emissions surcharge (which can be up to S$20,000 (approximately IND 1.1 million) for cars and S$30,000 (approximately IND 1.6 million) for taxis) or even a rebate (of the same magnitude as the surcharges). The VES band is determined by the vehicle's emissions of CO_2, HC, CO, NOx, and PM; the band corresponds to the worst-performing pollutant. Previous versions of the VES considered only CO_2 emissions. The ETS entitles you to benefits when you replace your older diesel goods vehicles and

[161] Cambridge City Council Air Quality Action Plan 2018 – 2023, 2019, p.38-39, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf
[162] Europe's giant 'taxi' company: is Uber part of the problem or the solution?, https://www.transportenvironment.org/sites/te/files/T%26E_Europe%20s%20giant%20taxi%20company%20is%20Uber%20part%20of%20the%20problem%20or%20the%20solut...%20%281%29.pdf
[163] Uber adds to pollution and traffic in European cities too, https://www.transportenvironment.org/press/uber-adds-pollution-and-traffic-european-cities-too
[164] Vehicle Emission Schemes in Singapore, https://onemotoring.lta.gov.sg/content/onemotoring/home/buying/upfront-vehicle-costs/emissions-charges.html

buses with more environmentally friendly models. A discounted Prevailing Quota Premium (PQP) for the vehicle's Certificate of Entitlement (COE) can be claimed when you replace your existing vehicle with a more environmentally friendly model.[165] Once the older vehicle has been deregistered, the replacement vehicle must be registered within a month, and existing and replacement vehicles must meet the eligibility criteria to qualify for the ETS. In general, the requirement for the replacement vehicle is Euro 6/VI. The NEA is set to introduce the Commercial Vehicle Emissions Scheme (CVES) for all new and used imported LGVs, Goods-cum-Passenger Vehicles (GPVs), and small buses from April 2021 to March 2023.

Under Cambridge's AQAP, Cambridge City Council in the UK has revised the taxi licensing policy to offer fee discounts for low emission taxis. A total of £140,245 (approximately IND 14 million) in funds has been committed (in 2018) to go towards fee reductions over 5 years to incentivise low and ultra-low emission taxi uptake. A minimum of 14 taxis per annum are expected to be impacted, from 2018/19 onwards.[166] There is also a low emission vehicle discount offered as part of a policy for residents' parking permits, promoting low emission vehicles to be used for personal vehicles. If a vehicle has CO_2 emissions of less than 75 grams per kilometre, the owner is entitled to a 20% discount of the full cost of a resident permit.[167] A workplace travel plan and school travel plan are planned to promote travel alternatives for commuting journeys, for instance by giving 10% rail discounts to 'Travel for Cambridgeshire' (TfC) partners.[168] TfC is Cambridgeshire's largest sustainable travel membership association, promoting travel alternatives such as walking, cycling or car sharing.[169]

The city of Hamburg in Germany has one of the best examples of EV infrastructure in Europe (see Section 4.3.3), and a key contributor to its success is the incentives available for EVs which can be found on the dedicated website to electromobility.[170] This website provides key information on the funding available for those who wish to switch to an EV, including a comprehensive list of current EV models for private and commercial use, with the list price and range, and a downloadable compact profile for each vehicle with further detailed information.[171] There are two funding instruments for EVs: the environmental bonus and the investment cost subsidy. The "environmental bonus" ("innovation bonus") can be granted to companies and private individuals for the purchase of EVs and, depending on the degree of electrification and the net list price of the vehicle, up to €9,000 (approximately IND 790,000) can be claimed. In order to receive this funding, which comes from the Federal Ministry of Economics, an application must be submitted to the responsible Federal Office for Economics and Export Control (BAFA). The second option, the investment cost subsidy, is for companies and municipalities. For this type of funding, an application must first be submitted to the responsible Federal Ministry (usually the Federal Ministry of Transport and Digital Infrastructure). The person who bears and provides evidence of the costs (i.e. the buyer) is entitled to apply. In both of the funding options, the respective applicant receives the funding as a direct, non-repayable grant. While a company uses this subsidy to reduce procurement costs, the leasing company passes the subsidy directly on to the lessee in the form of a special payment in the leasing contract, so that the EV can be offered at a discounted leasing rate. Further information about the amount of subsidy available under each funding scheme, as well as calculation examples, can be found on the website.

Other incentives for clean vehicles in Hamburg include vehicle tax exemptions for EVs and free parking for EVs at all parking machines. Pure EVs are exempt from vehicle tax for 10 years under the Motor Vehicle Tax Act (KraftStG).[172] The tax exemption for EVs is up to 10 years if they are first registered

[165] Early Turnover Scheme in Singapore, https://onemotoring.lta.gov.sg/content/onemotoring/home/buying/vehicle-types-and-registrations/commercial-vehicle/early-turnover.html
[166] Cambridge City Council Air Quality Action Plan 2018 – 2023, 2019, p.38-39, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf
[167] Residents parking in Cambridge, 2021, https://www.cambridgeshire.gov.uk/residents/travel-roads-and-parking/parking-permits-and-fines/parking#:~:text=If%20your%20vehicle%20has%20emissions,logbook)%20document%20for%20the%20vehicle.
[168] t4c discounts leaflet, 2015, https://www.environment.admin.cam.ac.uk/files/travel_discounts.pdf
[169] Cambridge City Council Air Quality Action Plan 2018 – 2023, 2019, p.51-78, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf
[170] Electromobility in Hamburg, https://elektromobilitaethamburg.de/
[171] How does funding work? Electromobility in Hamburg, https://elektromobilitaethamburg.de/wie-funktioniert-foerderung/
[172] Vehicle tax exemption for e-vehicles, Hamburg, https://elektromobilitaethamburg.de/e-fahrzeuge/privat/kfz-steuerbefreiung/

between May 18, 2011 and December 31, 2025. This offer runs until December 31, 2030 at the latest. The vehicle tax to be paid is then reduced by 50% going forward. Since November 1, 2015, EVs have been allowed to park free of charge at all parking ticket machines in Hamburg and all Park & Ride sites, for the maximum parking time.[173] In order to benefit from this, the vehicle must have an E-license. If the electric vehicle is already registered, the owner can apply for a new license plate with an -E- added to the end.

One of the co-benefits of incentivising cleaner vehicles is that it can generate positive publicity around EVs and other low emission vehicles; if someone has been able to save money by upgrading to a low emission vehicle then they are likely to promote the scheme, causing further upgrades. Therefore, incentivising cleaner vehicles can also lead to reduced fuel and maintenance costs for drivers. Preferential parking policies and traffic management measures for cleaner vehicles are likely to reduce the number of vehicles on the roads in general, which can help ease congestion in cities as well.

[173] Electromobility FAQs, Hamburg, https://www.hamburg.de/bwi/elektromobilitaet/14215236/elektromobilitaet-faq/

4.2.4 Evaluation of fuel switching measures

The fuel switching measures described above have been evaluated according to the criteria outlined in Section 4. Table 2 provides a summary of the results.

Table 2: Evaluation of fuel switching measures

Measure	Which pollutants are impacted?	Evaluation according to criteria					
		Air quality impact (1-5)	Costs (1-5)	Co-benefits (1-5)	Reliance on other measures (1-5)	Innovation (1-5)	Prospective timescale (1-5)
Low-emission bus fleets including retrofitting	**NOx, PM, SO_2**	✓✓✓	✓✓	✓✓✓	✓✓✓✓	✓✓✓✓	✓✓✓✓
Upgrade taxis including retrofitting	**NOx, PM**	✓✓	✓✓	✓✓✓	✓✓✓✓✓	✓✓✓✓	✓✓✓
Incentives for cleaner vehicles	**NOx, PM**	✓✓✓✓	✓✓	✓✓✓	✓✓✓✓	✓✓✓✓	✓✓✓

4.3 New technologies

4.3.1 Electric buses

Most 'traditional' buses are diesel vehicles, which are particularly polluting, especially for particulate matter. More and more cities are switching all or part of their diesel bus fleets to hybrid or electric buses. A key benefit of replacing diesel buses with electric buses is that the emissions impact can be felt straightaway.

The largest barrier to implementing electric buses is the investment cost of a new electric bus. The investment includes the cost of the actual vehicle(s), but also the EV infrastructure required to run the fleet. Funding may be available from the national government, or alternative sources (see below).

The Government of West Bengal (GoWB), India, aims to introduce electric buses in Kolkata in order to reduce emission levels. Conventional diesel-based buses contribute 33% of PM emissions in the city. Within the AQAP for Kolkata, medium-term measures toward this goal include the introduction of battery-operated buses; making a connection between electric mobility and the local public transport strategy; implementing an electric bus transport strategy (with procurement and deployment strategy) and developing infrastructure for charging and battery disposal.[174] Currently, 80 electric buses and 60 CNG buses have introduced to Kolkata by West Bengal Transport Corporation (WBTC) and South Bengal State Transport Corporation (SBSTC) respectively.[175] The GoWB aims to convert 100% of the WBTC bus fleet into an EV bus fleet by 2030 and has set a target to attract an investment of over INR 30,000 Crores (equivalent to USD $3.95 billion) for policy implementation of e-mobility.[176] If all city buses are converted to a fleet of 5,000 EV buses by 2030, this measure is expected to reduce cumulative CO_2 emissions by 782,560 tonnes, and significantly reduce PM emissions.[177]

In February 2018, the European Commission approved a German state aid scheme supporting acquisition of electric and plug-in hybrid buses to replace conventional diesel buses in public transport.[178] The initial funding amount was €70 million (approximately IND 6.1 billion), and was increased in May 2018 by a further €22 million (approximately IND 1.9 billion).[179] The scheme covers some of the costs of acquisition of electric and plug-in hybrid buses over conventional diesel buses, as well as the construction of the related electric charging infrastructure required for the operation of these buses, and applies to public transport operators only. To qualify for the support, public transport operators must ensure that their electric and plug-in hybrid buses are operated with electricity from renewable sources.

The city of Reutlingen in south-west Germany, in their 2018 "Master plan for the design more sustainable and emission-free mobility"[180], pledged to convert three bus routes to electric buses by 2019, and ensure 30% of all buses on the district bus routes are electric by 2025. The city was expecting to receive funding for up to 40% of the cost of purchasing diesel-electric hybrid buses and up to 80% of the cost of purchasing fully electric buses through the above fund. Although implementation costs are high, the running costs of EV buses are reasonable and with less moving parts than conventional buses, maintenance costs should be lower. Replacement of diesel buses with EV buses should immediately have an impact on air quality, as a significant proportion of emissions are immediately removed.

[174] Comprehensive Air Quality Action Plan for Kolkata, 2018, p.16-17, available online at: https://cpcb.nic.in/Actionplan/West%20Bengal.pdf
[175] Successful operation of electric bus fleet, 2020, available online at: https://iea.blob.core.windows.net/assets/db408b53-276c-47d6-8b05-52e53b1208e1/e-bus-case-study-TERI-Kolkata.pdf
[176] Successful operation of electric bus fleet, 2020, p.7, available online at: https://iea.blob.core.windows.net/assets/db408b53-276c-47d6-8b05-52e53b1208e1/e-bus-case-study-TERI-Kolkata.pdf
[177] Successful operation of electric bus fleet, 2020, p.5, available online at: https://iea.blob.core.windows.net/assets/db408b53-276c-47d6-8b05-52e53b1208e1/e-bus-case-study-TERI-Kolkata.pdf
[178] State aid: Commission approves €70 million public support scheme for electric buses and charging infrastructure in Germany, https://ec.europa.eu/commission/presscorner/detail/en/IP_18_1222
[179] SA.50776 Amendment of Support scheme for the acquisition of electric buses for urban public transport, https://ec.europa.eu/competition/elojade/isef/case_details.cfm?proc_code=3_SA_50776
[180] Master plan for the design more sustainable and emission-free mobility, Green City Plan Reutlingen, 2018, available online at: https://www.reutlingen.de/de/Rathaus/Rathaus-Themen/Verkehr-und-Mobilitaet/Green-City

Dortmund, also in Germany, will have an additional 30 EV buses in operation by mid-2022.[181] The public transport operator DSW21 already has one of the most modern bus fleets in North Rhine-Westphalia, with 172 diesel and hybrid buses that all meet the required Euro VI standard of the city (to carry a green sticker and operate in the centre). However, the €24 million (approximately IND 2.1 billion) investment will further modernise the fleet and reduce emissions. The procurement of EV buses is part of the "StromFahrer" project, under which the city predicts a reduction in NOx emissions of 40% by 2022, through the buying of non-conventional vehicles.

HOCHBAHN provides extensive bus mobility throughout the city of Hamburg in Germany: 114 bus routes covering over 920 km and 1,300 bus stops, with greater than 800 vehicles in operation.[182] The bus fleet is varied, with smaller city buses as well as double-articulated buses, as well as being accessible for wheelchairs, pushchairs, and bicycles. In the city alone, the bus network travels approximately 137,000 km every day – therefore the power behind this bus fleet is very important for the air quality in Hamburg. Since 2014, HOCHBAHN has been testing alternative driving technologies and gradually turning over their fleet from entirely diesel-fuelled buses to zero-emission electric buses. The number 109 route was the first "Innovation Line" in Europe, running 9.3 km from the Alsterdorf district via Winterhude to the city centre and back.[183] All of the innovative drivetrains were tested under the same trial conditions in daily operation on this route. This provided the best possible overview of the advantages and disadvantages of the individual technologies, and enabled HOCHBAHN to settle on the EV bus concept. In 2017, HOCHBAHN won the EBUS Award (an important national environmental prize in public transport awarded to companies that have successfully implemented projects and products for the introduction of electric buses) for commitment to emission-free transportation. In 2018, the first production-ready zero-emission EV buses arrived at HOCHBAHN and since then, procurement initiatives have been agreed with other transport companies in major German cities including Berlin to help their transition to zero-emission transport. For example, the transport companies have defined common standards in order to give manufacturers incentives to develop vehicles ready for series production for the German market (such as a minimum range requirement for an electric bus of at least 150 km). As part of the existing fleet renewal policy, Hamburger HOCHBAHN has replaced more than 60 buses of older emissions standards with newer ones (at least Euro VI), every year.[184] From 2020 the two public providers of bus services, HOCHBAHN and VHH, will only purchase zero-emission buses.

Hamburg HOCHBAHN also leads a project "Hamburg Electric Autonomous Transportation" (HEAT),[185] a unique research and development project that aims to integrate an autonomous shuttle bus into regular street traffic in Hamburg. The minibus, shown in Figure 9, is five metres long, weighs just under three tonnes, can hold ten passengers, and is powered entirely by electricity. The inside comprises two benches with four seats each, a foldable bench with two additional seats, and an access ramp enabling barrier-free access. The HEAT minibus will be tested under real conditions in public and is said to be capable of autonomous driving at speeds up to 50 km/h. To achieve this goal whilst remaining safe, the minibus is equipped with cameras, radar and lidar, as well as supplementary intelligent infrastructure along its route (sensors and a digital communications system) to keep the vehicle in constant digital communication with its surroundings and the central HOCHBAHN control. The HEAT project has a step-by-step approach to testing, first with the minibus running along a defined route without passengers and accompanied by a professional vehicle attendant who can immediately take control if necessary. In mid-2020, the minibus was to begin operating with passengers as well as a vehicle attendant on board. By the time the Intelligent Transport Systems (ITS) World Congress opens in October 2021, it is hoped that the minibus will be operating autonomously according to the Society of Automotive Engineers (SAE) Level 4 specifications, i.e. that the vehicle is able to intervene itself if something goes

[181] Dortmund's public transport fleet to be strengthened by 30 new electric buses, https://www.themayor.eu/de/a/view/dortmund-s-public-transport-fleet-to-be-strengthened-by-30-new-electric-buses-6031
[182] The bus network, HOCHBAHN, Hamburg, https://www.hochbahn.de/hochbahn/hamburg/en/home/transport/means_of_transport/bus
[183] HOCHBAHN projects, Zero-emission buses, Hamburg, https://www.hochbahn.de/hochbahn/hamburg/en/home/projects/expansion_and_projects/zero_emission_buses
[184] Master Plan for Designing More Sustainable and Emission-Free Mobility in Hamburg as part of the Immediate Program for Clean Air 2017 – 2020, 2018, available online at https://www.bmvi.de/SharedDocs/DE/Anlage/K/Masterplaene-Green-City/hamburg.pdf?__blob=publicationFile
[185] HEAT: Hamburg Electric Autonomous Transportation, Hamburg, https://www.hamburg.com/business/its/12778724/heat/

wrong or there is a system failure. Currently, a HEAT app can be downloaded to your smartphone and you can request to ride the HEAT minibus for free – a good piece of publicity for the project.[186] The city of Hamburg has a total of €3.7 million (approximately IND 325 million) in funding for the HEAT project. Hamburg's Ministry for Economics, Transport, and Innovation (BWVI), the city's Department of Roads, Bridges and Water (LSBG) and Hamburg Verkehrsanlagen GmbH (HHVA) account for €2.7 million (approximately IND 237 million) of this sum. HOCHBAHN is receiving around €1 million for the project management and providing a further €1.5 million (approximately IND 132 million) from its own budget. Project partners include Hamburger HOCHBAHN AG, IAV, Siemens Mobility GmbH, IKEM – the Institute for Climate Protection, Energy and Mobility, and the German Aerospace Center e.V. (DLR).

Aside from reduction in pollutant emissions and greenhouse gas emissions, electric buses are significantly less noisy than diesel buses. This is particularly beneficial in locations such as cities where bus services may run late into the night and begin early in the morning to cover all public transport needs.

Figure 9: The HOCHBAHN Hamburg Electric Autonomous Transportation (HEAT) vehicle[187]

4.3.2 Electric taxis

Where vehicle upgrades are concerned, the greatest improvements in air quality are likely to come from upgrading the vehicles with the highest daily mileage. For example, replacement of a diesel taxi that travels all day every day with an electric vehicle, will remove more emissions from the roads than replacement of one diesel private vehicle that makes fewer, shorter trips per day.

It is vital that expansion and maintenance of the electric vehicle charging infrastructure in a city is developed with the increasing number of electric vehicles. In addition, taxi companies / owners are unlikely to upgrade their taxi(s) without incentives and support. Incentives for upgrading / replacing taxis may include tax breaks, EV-only taxi ranks with chargers, scrappage schemes or even grants for purchasing an EV or low-emission taxi. Promotion of low emission taxis including the benefits and incentives available should be targeted at taxi companies / owners – it should also be publicised the less obvious benefits such as some people choosing to travel in a low-emission taxi over a traditional one because of their environmental beliefs.

[186] Project HEAT, HOCHBAHN, Hamburg, https://www.hochbahn.de/hochbahn/hamburg/en/home/projects/expansion_and_projects/project_heat
[187] Project HEAT, HOCHBAHN, Hamburg, https://www.hochbahn.de/hochbahn/hamburg/en/home/projects/expansion_and_projects/project_heat

In Kolkata, a measure is already in place aiming to operationalise E-Rickshaws and E-Carts as the main mode of transport for 'last mile' connectivity. Due to an order from the Hon'ble High Court of Kolkata, currently all three-wheeler taxis operating in Kolkata City are four-stroke liquefied petroleum gas (LPG) Autos (which fall within the category of green vehicles). E-Rickshaws are also operating and are registered by the Transport Department in Howrah City (part of the Kolkata Metropolitan Area) and Salt Lake area, which falls under Kolkata Metropolitan Development Authority (KMDA). These E-Rickshaws are providing last mile connectivity and reducing the auto emissions at the fringe of Kolkata.[188] Energy consumption by E-rickshaws (53.76 kJ/km) has been found to consume much less energy than other modes of transport in Kolkata, including private buses (158.45 kJ/km) and traditional auto-rickshaws (362.4 kJ/km).[189] In 2020, the company Uber introduced 500 E-rickshaws to Kolkata, making commutes more affordable, efficient and eco-friendly.[190]

In Oxford (UK), a measure promoting zero-emission vehicles in the light duty fleet (cars, vans, and taxis) is planned, aiming to facilitate a 10% uptake of EVs by 2020. This requires the development of charging infrastructure, introducing EVs into the council fleet and working with partners to introduce EVs into business fleets.[191] The first electric taxi was announced in Oxford in April 2019, and the City Council is actively encouraging further taxis to make the change to electric through financial incentives, engagement events and an the development of a local taxi rapid charging network, funded by a £500,000 (approximately IND 50 million) grant from the OLEV.[192]

The city of Reutlingen in Germany, as part of their 2018 "Master plan for the design more sustainable and emission-free mobility"[193], plans to increase the number of electric taxis along with some of the municipal vehicles. There is not much information on the plan, however, there are two funding programmes mentioned. The renewable mobile funding program (Förderprogramm Erneuerbar Mobil) would likely provide 40% - 60% of costs, and the electromobility funding guidelines (Förderrichtlinie Elektromobilität) suggest up to 75% of costs of new vehicles could be funded. Although implementation costs of electric taxis are high, the running costs of EV vehicles are reasonable and with less moving parts than conventional taxis, maintenance costs should be lower. Replacement of conventional taxis with electric taxis should immediately have an impact on air quality, as pollutant emissions are immediately removed.

In Hamburg in Germany, there are a number of carpooling / shuttle services – many are start-ups. This has led to Hamburg being described as "*the leading position in eco-friendly ride pooling on the European continent*".[194] CleverShuttle calls itself "the greenest shuttle in the world" and has been in operation since 2017. The service uses EV, hydrogen and hybrid vehicles for on-demand carpooling / carsharing. CleverShuttle operates Europe's largest hydrogen fleet for individual public transportation and is one of the more affordable transport services in Germany.[195] Deutsche Bahn's business unit for intelligent on-demand mobility and the public transport provider VHH began to offer a new public on-demand shuttle service in two outer quarters of Hamburg in summer 2018. "ioki" is a ride sharing concept that allows up to six passengers to book the same (zero-emission) shuttle via an app, at the HVV rates.[196] MOIA, a mobility start-up, is part of the Volkswagen Group and an EV has been developed specifically for this shared journey mobility service. In April 2019, MOIA launched its services with a fleet of 100 vehicles, with scheduled growth to 500 vehicles by the end of 2019. Users book their shuttle

[188] Comprehensive Air Quality Action Plan for Kolkata, 2018, p.16-17, available online at: https://cpcb.nic.in/Actionplan/West%20Bengal.pdf
[189] Merits and Challenges of E-Rickshaw as An Alternative form of Public Road Transport System: A Case Study in the State of West Bengal in India, 2015, p311, available online at: https://www.sciencedirect.com/science/article/pii/S1876610215022249
[190] Uber launches 500 e-rickshaws in Kolkata to make urban commutes more sustainable, 2020, https://economictimes.indiatimes.com/tech/startups/uber-launches-500-e-rickshaws-in-kolkata-to-make-urban-commutes-more-sustainable/articleshow/79307197.cms?from=mdr
[191] Oxford Low emission strategy, 2013, p.20, available online at: https://www.oxford.gov.uk/downloads/download/156/low_emission_strategy
[192] Oxford gets its first electric private hire car, 2019, https://www.oxford.gov.uk/news/article/1118/oxford_gets_its_first_electric_private_hire_car
[193] Master plan for the design more sustainable and emission-free mobility, Green City Plan Reutlingen, 2018, available online at: https://www.reutlingen.de/de/Rathaus/Rathaus-Themen/Verkehr-und-Mobilitaet/Green-City
[194] Mobility Lighthouse Projects, Hamburg, https://marketing.hamburg.de/mobility-lighthouse-projects.html
[195] CleverShuttle, Hamburg, https://www.clevershuttle.de/en/company
[196] ioki, Hamburg, https://ioki.com/en/

bus via an app, specifying the start and destination of their intended journey; an algorithm then bundles the trip with similar routes of other users and calculates individual prices depending on the length of the route.[197] Finally, mytaxi (originally launched in 2009 as Europe's first taxi app) now also covers the city of Hamburg and allows customers to share their trips with other people using the mytaximatch feature. A new pricing model was developed by Hamburg's taxi companies in liaison with the City of Hamburg; the aim was to provide passengers with maximum transparency. Prior to booking a trip, the app calculates a fixed price (no taximeter) so customers know what they will pay.[198]

One possible co-benefit of this measure is increased publicity and therefore business for local taxi companies. As discussed above, some travellers may choose a low emission taxi for their journey over a traditional taxi because of their environmental beliefs. As schemes and incentives for upgrading taxis need to be well publicised, this in turn could provide increased publicity for the taxi owners / companies that have taken advantage of the schemes.

4.3.3 Comprehensive electric charging infrastructure including e-charging hubs

This measure relies on the assumption that the improvement of electric vehicle infrastructure including additional charging facilities and preferential parking policies, will result in a change in the fleet composition via a greater uptake of electric vehicles.

There are a number of components to consider within the implementation of EV infrastructure:

- Power supply and connection to the grid (voltage, appropriate cabling)
- Current network of EV chargers (including location of chargers and types of chargers – slow, medium, fast, rapid)
- Demand for public, workplace, and residential chargers
- Current provision of EVs in the city (cars, buses, taxis, e-bikes, etc.)
- Current funding / grants available for those who wish to purchase an EV
- Any other incentives for purchasing an EV (tax breaks, free parking, etc.)

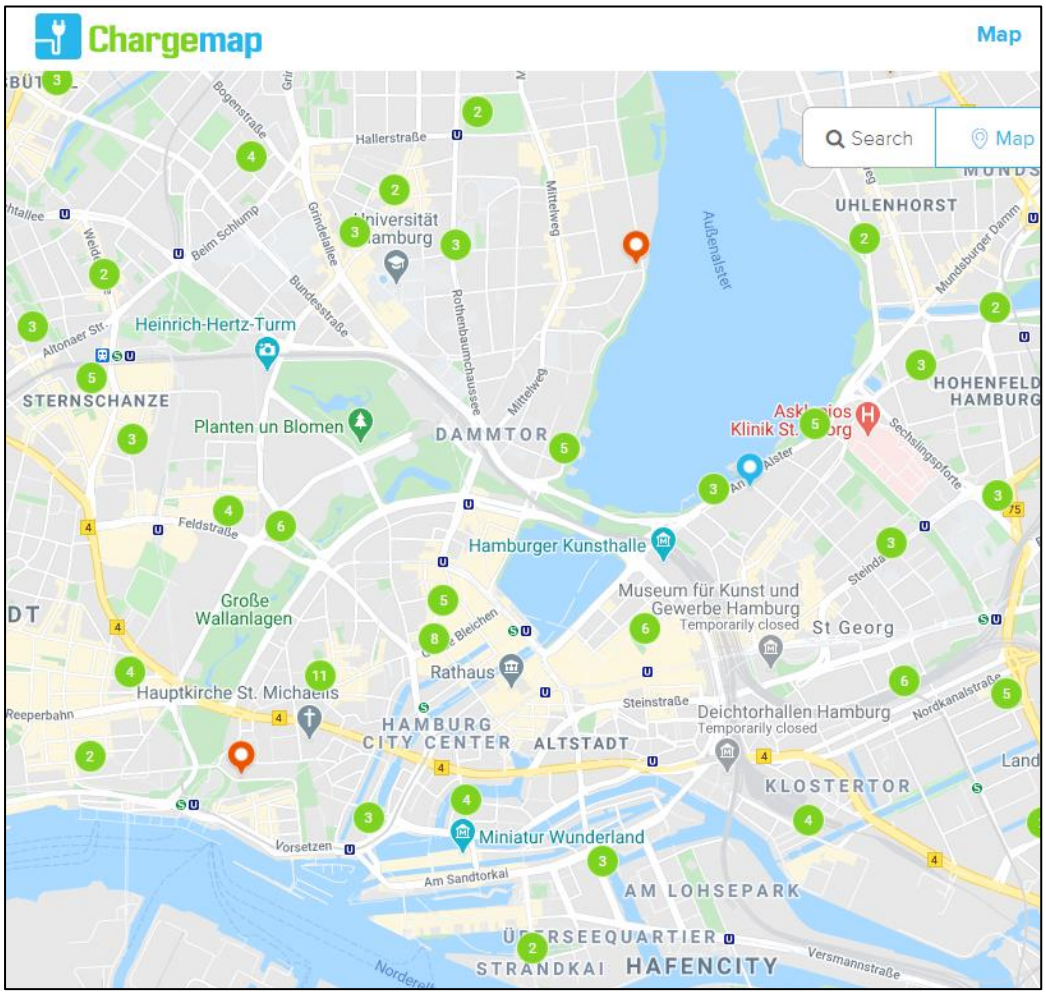
A key objective in the Cambridge (UK) AQAP is to encourage, enable and require, the shift to low emission petrol hybrid and ULEVs. Measures to implement this are identified as; provision of EV charging points (slow, fast and rapid) for residents, non-residents and taxis; ensuring new development plans enable charging in safe, accessible and convenient locations; developing policies to require electric bike charge hubs and parking in new residential areas without off street parking; promoting electric bike charge facilities in workplaces and car parks and installing EV charge points on lampposts, for residents and non-residents, at all large scale major sites and any new or replacement car parks.[199] Electric charge points are now available at two car parks, four park & ride facilities and several business and hotel locations in Cambridge, with more planned to be added to residential and commercial parking facilities. There are also eight charge points specifically for local taxis, with plans to install 16 more by 2021. Planning policy now requires the installation of charging points in new developments with parking provision, and government funding (via the OLEV) is available to support homeowners to install charge points at their own property.[200]

Hamburg in Germany has been incorporating EV infrastructure into the city for over ten years, and is a really great example of continued development of the infrastructure. By 2019, under the Master Plan for Charging Infrastructure, 1,000 charging points for electric vehicles were planned to have been built around the city (70 of them fast chargers), with an additional 150 charging points exclusively for car share use – this has reportedly been achieved.[201] Electric vehicle charge points in Hamburg can be located using the mapping service ChargeMap, as shown in Figure 10. Extensive parking facilities are also envisaged for EVs and car sharing cars. A dedicated website to electromobility provides a number of useful webpages detailing the subsidies available to those wishing to purchase an EV, explains other

[197] MOIA, Hamburg, http://www.moia.io/
[198] mytaxi, Hamburg, http://www.mytaxi.com/
[199] Cambridge City Council Air Quality Action Plan 2018 – 2023, 2019, p.51-78, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf
[200] Electric vehicle charging points, Cambridge, https://www.cambridge.gov.uk/electric-vehicle-charging-points
[201] New urban mobility measures planned in Hamburg (Germany), https://www.eltis.org/discover/news/new-urban-mobility-measures-planned-hamburg-germany

incentives such as tax breaks, and also provides information about public and commercial charging infrastructure.[202] A charging map from Stromnetz Hamburg shows all charging points and their availability; currently they alone operate approximately 585 chargers in the greater Hamburg area.[203] Another example of the continuously expanding charging infrastructure is the number of payment options available to those who wish to charge their EV at a public charge point in the city. Spontaneous access (charging via SMS or app) was introduced at all charging stations in 2015.[204] The E-charging Hamburg website explains how to use each of the four payment options: SMS, app (both Direct Pay), charging card (Radio Frequency Identification Card, RFID) and billing. Hamburg is to host the Intelligent Transport Systems (ITS) World Congress in October 2021,[205] demonstrating its commitment and prowess in the field of smart mobility, including innovative EV infrastructure.

Figure 10: Map of electric vehicle charge points in Hamburg, Germany based on information from the service ChargeMap[206]



Aside from reduction in pollutant emissions and greenhouse gas emissions, EVs are significantly less noisy than 'conventional' vehicles. This is particularly beneficial in locations such as cities where traffic may travel early in the morning and late at night. Increasing EV infrastructure makes it easier for residents to transfer to an EV, as worries regarding where and when they will be able to charge their vehicles become minimised. Those who own an EV may be able to benefit from reduced fuel costs and some free charging in certain locations; EVs also have fewer moving parts than 'conventional' cars and so are potentially less likely to break down.

[202] Electromobility in Hamburg, https://elektromobilitaethamburg.de/
[203] Stromnetz, Hamburg, https://www.emobility-partner.de/karte/hamburg
[204] E-charging in Hamburg, https://www.e-charging-hamburg.de/so-funktionierts/
[205] ITS World Congress 2021, https://itsworldcongress.com/?cookie-state-change=1612172941002
[206] Chargemap, 2021, available online at: https://chargemap.com/map

4.3.4 E-bikes / pedelecs including E-delivery vehicles

Cargo bikes, especially in the form of e-cargo bikes, offer great potential for urban freight transport. They can transport heavy loads (up to 200 kg plus the driver), use paths that cannot be accessed by motor vehicles and therefore can reach almost all destinations. They generate no noise and no exhaust emissions, meaning they can be used during unsociable hours. With a range of up to 180 km, they are reported to be very cost-effective compared to classic delivery vans.

E-delivery vehicles can be used for both commercial and private use. For commercial use, mechanisms to facilitate uptake mainly focus around grants or other incentives to purchase the bikes (such as access to areas that other vehicles are unable to or are banned from accessing). For private use, in addition to grants to aid in the purchase of a vehicle, e-cargo bikes should be able to be rented for little to no cost.

The city of Reutlingen, in Germany, wishes to set an example by using e-cargo bikes in the hope that businesses will also consider them, according to the 2018 "Master plan for the design more sustainable and emission-free mobility".[207] The city administration and municipal institutions plan to demonstrate the use of e-cargo bikes, especially the up to 200 kg transport capacity. They state that the e-cargo bikes will be most useful in reaching the sensitive parts of the city, such as the historic centre, where traditional delivery vehicles struggle to reach. If businesses choose to make use of e-cargo bikes, the uptake would help make a case for cycle infrastructure, and more specifically e-bike infrastructure, in the city to be expanded and improved. Key considerations are separate e-bike parking facilities with chargers and extra security, ensuring the cycle network can accommodate pedal bikes and e-bikes, and the potential for e-bike rental schemes for private use.

Herrenberg, in Germany, is able to provide grants for e-cargo bikes through the Ministry of Transport Baden-Württemberg (the state in which Herrenberg is located). The state initiative 'III Marktwauten Elektromobilität BW' can provide up to 30% of the cost of a new e-cargo bike, up to €3,000 (approximately IND 264,000) per bike.[208] The e-cargo bike must be of the EC vehicle classes L1e to L5e, or an electric cargo bike with a maximum speed of up to 25 km/h for the transport of goods, materials or people. Companies and corporations, freelancers and non-profit organisations can apply for the grant, which is approved and provided via the L-Bank.

Berlin, the capital city of Germany, provides free rental of e-cargo bikes under the 'fLotte kommunal' scheme.[209] The scheme is run by the German Bicycle Club Berlin e.V. (ADFC Berlin). Anyone who needs a cargo bike can borrow one for free in an uncomplicated manner in many districts of the city. There are approximately 120 cargo bikes available at present, often located at places such as neighbourhood facilities, organic markets, and bike shops. The scheme relies on partners to act as sponsors and fix the e-cargo bikes if one should break down.

Also in Berlin, e-cargo bikes are being encouraged instead of delivery vans. The KoMoDo project[210] was a one-year trial involving e-cargo bikes being used for the last-mile delivery of packages. As a result, a reported 28,000 km of journeys by vans were avoided, and 160,000 parcels were delivered by 11 cargo bikes in an area with a radius of 2 – 3 km. Districts are now putting the experience obtained here to use in similar projects.

Part of the Cambridge (UK) AQAP to reduce emissions from HGVs is to encourage cycle deliveries instead, reducing the volume of freight deliveries. Under the plans, 'last mile' deliveries could be undertaken using EV cars, taxis and/or bicycles. These services are seen as commercially viable due to current successful services such as 'Deliveroo' or 'Outspoken Delivery', a local Cambridge courier service which use specialist cargo-bikes and EVs.[211] For example, Outspoken Delivery has around 20

[207] Master plan for the design more sustainable and emission-free mobility, Green City Plan Reutlingen, 2018, available online at: https://www.reutlingen.de/de/Rathaus/Rathaus-Themen/Verkehr-und-Mobilitaet/Green-City
[208] We promote your e-cargo bikes, Herrenberg, https://vm.baden-wuerttemberg.de/de/politik-zukunft/elektromobilitaet/foerderung-elektromobilitaet/e-lastenraeder/
[209] Cycling, Berlin, https://www.berlin.de/sen/uvk/en/traffic/transport-planning/cycling/
[210] KoMoDo city hub project in Berlin: It works! It's fun!, https://www.velove.se/news/komodo-city-hub-project-in-berlin-it-works-its-fun
[211] Cambridge City Council Air Quality Action Plan 2018 – 2023, 2019, p.51-78, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf

cargo bikes and tricycles which can be used for deliveries or rented by clients and in 2015, the company saved over 56 tonnes of CO_2 through delivery riders cycling over 126,000 miles.[212]

Cambridge is also encouraging the use of electric bikes through the development of electric bike hire / hub schemes.[213] This would provide an alternative to private vehicle use. Cambridgeshire and Peterborough Combined Authority have launched an electric bike scheme in Cambridge and Peterborough. The e-bike trial, which began in October 2020 in Cambridge, showed that there were more than 4,400 individual users so far. People can hire e-bikes which can travel between 50 – 100 miles on a single charge. The number of e-scooters in the city has also been increased from 50 to 350, providing an additional option for users. The local authority expects to save between 48 – 115 tonnes of CO_2 in Cambridge over the course of the trial.

E-cargo bikes are an environmentally friendly, inexpensive, and space-saving solution for commercial use as well as for the general public. Commercial deliveries, weekend shopping, transporting children or travelling around are all suitable uses with the additional benefits of increasing the fitness of the user and removing motor vehicle traffic from the roads. Another co-benefit of providing accessible e-bikes and e-scooters is the minimised transmission of Covid-19, as they provide a socially-distanced mode of travel and the handlebars can be disinfected every day.[214]

4.3.5 Compressed Natural Gas

Compressed natural gas (CNG) is an alternative fuel to fossil oil sources in transport, which can be used for cars, buses, light commercial vehicles, and trucks. With respect to local air pollutants, CNG powered vehicles are better than both diesel and petrol cars regarding PM emissions.[215] CNG can improve air quality through reduced particulate emissions as well as the reduction of GHG emissions. However, it has been noted that these benefits are minimal, since the extent to which the use of CNG reduces emissions depends on the engine efficiency compared to the current diesel fleet. For instance, CNG offers little benefit in terms of reduced NOx and PM emissions when compared to vehicles complying to Euro 6 standards, depending on vehicle type.

Introducing CNG as a measure to reduce emissions also depends on the development of refuelling infrastructure, which requires funding.[216] CNG can be introduced by giving tariff preference to CNG-driven buses.

Dhaka in Bangladesh is encouraging a switch from diesel to CNG, for all diesel vehicles. Pricing incentives are already in place; however, it can be problematic to increase the price of diesel since almost half of diesel is used in the agriculture sector. A potential solution to this is the introduction of a measure to subsidise CNG conversion equipment for diesel vehicles. Conversion of vehicles to run on CNG has largely contributed to the reduction of PM emissions in Dhaka. Since 2002, conversion of most personal vehicles to run on CNG has potentially made the on-road personal vehicles less polluting in terms of particulates, although ultrafine emissions may have increased. In Dhaka, a 2011 study estimated that 4,260 premature deaths had been avoided through conversion to CNG.[217]

In Lahore, Pakistan, the use of gas – especially in the form of CNG – within transport has been increasing, with total CNG consumption increasing by 84% from 1997/98 to 2006/07. However, there has been a slower growth (4%) in more recent years (2006/07 to 2008/09). A key policy option for Lahore is to convert diesel-fuelled minibuses and vans as well as three-wheelers (rickshaws) to CNG,

[212] Outspoken Delivery, Cambridge & Norwich, https://como.org.uk/project/outspoken-delivery-cambridge-norwich/
[213] Cambridge City Council Air Quality Action Plan 2018 – 2023, 2019, p.51-78, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf
[214] Cambridgeshire and Peterborough Combined Authority to launch Electric bikes in Cambridge and Peterborough from January, https://cambridgeshirepeterborough-ca.gov.uk/news/cambridgeshire-and-peterborough-combined-authority-to-launch-electric-bikes-in-cambridge-and-peterborough-from-january/
[215] CNG and LNG for vehicles and ships - the facts, 2018, p.32, available online at: https://www.transportenvironment.org/sites/te/files/publications/2018_10_TE_CNG_and_LNG_for_vehicles_and_ships_the_facts_EN.pdf
[216] CNG and LNG for vehicles and ships - the facts, 2018, p.26-36, available online at: https://www.transportenvironment.org/sites/te/files/publications/2018_10_TE_CNG_and_LNG_for_vehicles_and_ships_the_facts_EN.pdf
[217] Air Pollution Reduction Strategy for Bangladesh, 2012, p.31 available online at: http://old.doe.gov.bd/publication_images/60_air_pollution__reduction_strategy.pdf

which could potentially bring substantial emission reduction of PM, as CNG powered vehicles emit very little PM. Since CNG supply can be constrained, it has been advised that a priority for conversion to CNG be reserved for commercial vehicles where the greatest impact can be made. Conversion of commercial vehicles to CNG in Pakistan was reported to cost in the range of US$1,900 – US$2,550 at the exchange rate of 2009. Applying a cost of PRs (Pakistani Rupee) 200,000 (approximately IND 91,000), the average estimate of the cost-benefit ratios on conversion to CNG are 1.7 for minibuses and 1.2 for light duty vans, but when fuel savings are taken into account, the cost-benefit ratio is as high as 4.2. CNG can be introduced by giving tariff preferences to CNG-driven buses. In Lahore, the Ministry of Energy (MoEn) is responsible for clean fuel imports and encouraging the use of CNG in vehicles and have already implemented schemes to convert rickshaws to CNG.

Fuel switching from coal, fuel oil, or diesel to CNG has the potential to bring about substantial improvements in local air quality and mitigate GHG emissions, as CNG produces less CO_2 per km of travel than most other fossil fuels. It has been estimated that natural gas-powered vehicles can reduce GHG emissions by as much as 20% – 25%, compared to vehicles that run on gasoline. The growth in the use of CNG in Pakistan has also provided economic benefits through employment generation and reduced dependence upon imported energy sources In 2009, the health benefits of CNG conversion were considered to be in the range of about US$455 – US$1,288 (approximately IND 33,000 – IND 94,000) per vehicle per year, depending on the type of vehicle and annual usage.[218]

4.3.6 Active dust binding

Dust binding refers to the spreading of liquid (often hygroscopic) solutions on paved streets to mitigate street dust emissions by keeping the road surface moist.[219] Dust binding as a measure is quick and easy to implement, improving the ability of maintenance organisations to both act proactively and to react to high ambient concentrations, although there may be a need to consider broader environmental impacts associated with the use of the chemicals. The measure also does not remove street dust, but binds it to the road surface, meaning the streets still need to be cleaned.[220] The various road dust and moisture processes are illustrated in Figure 11, highlighting the elements which need to be considered in relation to road dust, such as type of emissions and meteorology of the area.

The Nordic countries (Denmark, Finland, Norway, and Sweden) have made use of dust binding to mitigate PM emissions. Different solutions are available, including calcium magnesium acetate (CMA), magnesium chloride ($MgCl_2$) and calcium chloride ($CaCl_2$). The doses used have been reduced from several tens of grams per square metre in early tests, to the current level of about 10 – 20 g/m^2, due to a risk of reduced friction.[221] Dust binders are normally spread using rotating disc spreaders, or by spray nozzle ramp.

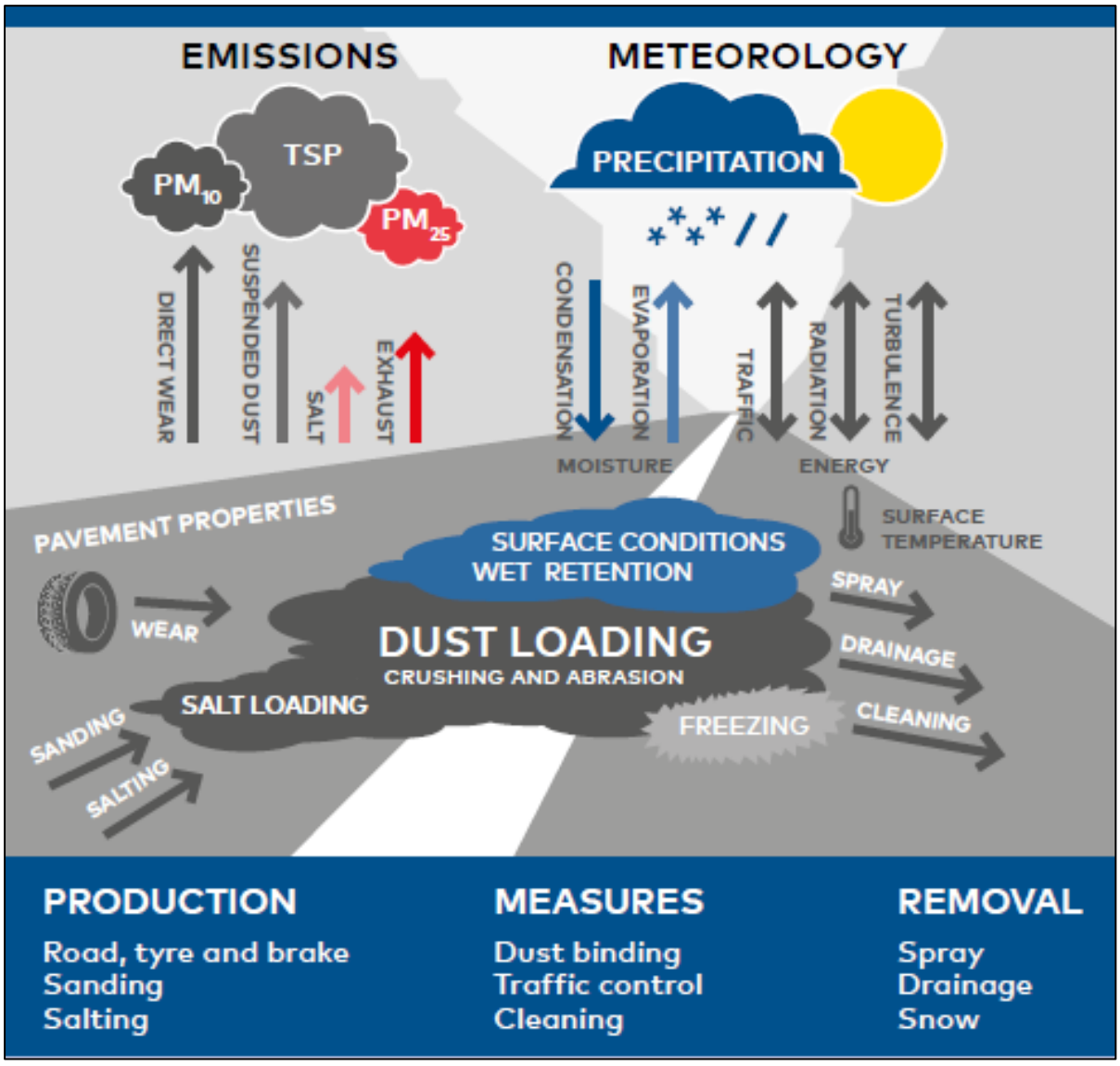
The city of Helsinki, capital of Finland, has implemented measures to reduce street dust including active dust binding and enhanced street cleaning. Enhanced cleaning and active dust binding with calcium chloride solution are seen as very effective methods to reduce high dust concentrations, as it avoids the spread of dust to nearby streets. This is particularly important near construction sites or where construction traffic travels, and can significantly reduce the health effects of street dust. Calcium chloride, a brine solution, is used for this purpose as it attracts moisture and resists evaporation-keeping road surfaces damp so that dust cannot be re-suspended into the air. Over time the solution can penetrate the road surface, creating a stabilising effect.[222] The effects of dust binding on street dust

[218] Cleaning Pakistan's Air, Policy Options to address the cost of outdoor air pollution, 2014, p.23-24 available online at: http://documents1.worldbank.org/curated/en/701891468285328404/pdf/890650PUB0Clea00Box385269B00PUBLIC0.pdf
[219] Code of good practices - Intensive street cleaning and dust binding to reduce re-suspension, Helsinki, 2018, available online at: https://ec.europa.eu/futurium/en/air-quality/code-good-practices-intensive-street-cleaning-and-dust-binding-reduce-re-suspension
[220] The City of Helsinki Air Protection plan 2017–2024, 2016, pp. 51-59, available online at: https://www.hel.fi/static/ymk/julkaisut/julkaisu-11-16.pdf
[221] Road dust and PM10 in the Nordic countries, Measures to reduce road dust emissions from traffic, Nordic Council of Ministers, 2017, available online at: https://norden.diva-portal.org/smash/get/diva2:1069152/FULLTEXT02.pdf
[222] Liquid Calcium Chloride for Dust Control and Base Stabilization of Unpaved Road Systems, 1991, p.173, available online at: http://onlinepubs.trb.org/Onlinepubs/trr/1991/1291vol1/1291-059.pdf

emissions were studied in the REDUST Life+ project[223] between 2011 – 2014. The results showed that targeted dust binding at street edges in the middle of lanes decreased street dust emissions by approximately 40%, two days after the action, and whole lane dust binding by approximately 60%, three days after the action.[224]

This measure improves air quality through the reduction of ambient PM, leading to health co-benefits such as reduced respiratory issues from dust inhalation, as well as reduced vehicle damage from dust and improved safety from an increase in visibility on the roads.[225]

Figure 11: The NORTRIP model of road dust and moisture processes, taken from Figure 2, Road dust and PM_{10} in the Nordic countries (2017)[226]



[223] REDUST - Best winter maintenance practices for respirable street dust reduction, https://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=3734
[224] The City of Helsinki Air Protection plan 2017–2024, 2016, pp. 51-59, available online at: https://www.hel.fi/static/ymk/julkaisut/julkaisu-11-16.pdf
[225] 6 benefits of an effective dust control program, https://www.oxycalciumchloride.com/building-better-roads/news-events/news/2019/05/04/6-benefits-of-an-effective-dust-control-program
[226] Road dust and PM10 in the Nordic countries, 2017, Figure 2, p.21, available online at: https://norden.diva-portal.org/smash/get/diva2:1069152/FULLTEXT02.pdf

4.3.7 Evaluation of new technologies measures

The new technologies measures described above have been evaluated according to the criteria outlined in Section 4. Table 3 provides a summary of the results.

Table 3: Evaluation of new technologies measures

Measure	Which pollutants are impacted?	Evaluation according to criteria					
		Air quality impact (1-5)	Costs (1-5)	Co-benefits (1-5)	Reliance on other measures (1-5)	Innovation (1-5)	Prospective timescale (1-5)
Electric buses	**NOx, PM, SO_2**	✓✓✓	✓	✓✓✓	✓	✓✓✓✓✓	✓✓
Electric taxis	**NOx, PM**	✓✓	✓	✓✓✓	✓	✓✓✓✓✓	✓✓
Comprehensive electric charging infrastructure	**NOx, PM, SO_2**	✓✓✓✓	✓	✓✓✓	✓	✓✓✓✓✓	✓
E-bikes / pedelecs including E-delivery vehicles	**NOx, PM, SO_2**	✓✓✓	✓✓	✓✓✓	✓✓	✓✓✓✓✓	✓✓✓✓
Compressed Natural Gas	**NOx, PM, SO_2**	✓✓	✓	✓✓	✓	✓✓✓✓	✓✓
Active dust binding	**PM**	✓✓	✓✓✓✓	✓	✓✓✓✓✓	✓✓✓✓	✓✓✓✓✓

4.4 Mode shift

4.4.1 Public transport infrastructure and service quality, including mapping passenger needs

Comprehensive public transport infrastructure is required to ensure that the public transport system is an attractive alternative to travelling via private vehicle. The passenger needs of each city will be slightly different, so it is vital to map these needs to see where there are gaps in the public transport network where improvements can be made.

Needs-based, fair transport services that are well integrated should be the aim to ensure that all residents, regardless of social status, have access to a wide range of mobility options. Central traffic hubs in the travel hotspots should be used as mobility stations, enabling users to switch to bus, rail, bike, or footpaths. The public transport system must have easy-to-understand mobility guidance and a simple payment system – ideally one that covers all mobility options in the city (see Section 4.4.2).

A proposed strategy to reduce air pollution from transport in large cities in Bangladesh, such as Dhaka, is to improve public transport with the hope that improvements will slow the growth rate in the number of privately owned vehicles. This measure would require the expansion of a bus rapid transit system and improved walking and cycling facilities, which depend on large capital investment. It is possible that air quality could deteriorate during the construction phases of mass rapid transits systems and expressways, however, it is expected that new and improved transport systems will bring substantial air quality improvements to the city in the medium-to-long term. Building expressways can alleviate congestion and therefore improve air quality in the short term, but for longer term improvements in congestion and emissions, mass transit is a preferred option. It is predicted that this action would have a large impact at a low cost because of the economic benefits, so it is noted as a high priority emission control strategy for Dhaka.

In Kolkata, India, it is established that improving public transport systems is a strong measure for emission reductions because approximately 88% of residents are dependent on bus, tram, rail, metro, or other forms of public transport. In comparison, only 12% are dependent on private vehicles like cars and two-wheelers. Buses make up around 18% of the vehicle fleet in Kolkata. A proposed short-term strategy to reduce vehicle numbers on the roads is to improve bus services by enforcing bus lanes, ensuring efficient bus depots, and ensuring an integration of the current metro system with the bus services (via optimising fleet utilisation of tramways, and increasing service frequency). In the medium-to long-term, bus numbers and services can be improved, for instance through an increase in the size of bus fleet, along with improved fuel efficiency and pollution reduction. The Transport Department has already issued an order for Kolkata Metropolitan Area restricting the use of vehicles which are more than 15 years old, and the GoWB is introducing electric buses in Kolkata to reduce vehicular emission levels (see Section 4.3.1). Further planned measures to improve services in Kolkata include route rationalisation (improving availability), installing and operating GPS units on buses and creating a traffic control unit to monitor bus movement, developing an IT system in buses, bus-stops and control centres to allow for more reliable passenger information systems and service monitoring, and finally examining the existing framework for removing broken down buses or trucks from roads to ensure minimal disruption to traffic.[227]

Previously, a priority action in the city of Oxford (UK)'s 2013 Low Emission Strategy was to develop a city-wide sustainable travel plan. The plan aimed to develop a more integrated approach to travel planning in the city, with an indicative target of a 10% reduction in car vehicle kilometres (vkm) by 2020.[228] This involved coordination between various already-existing plans: the Air Quality Action

[227] Comprehensive Air Quality Action Plan for Kolkata, 2018, p. 8-10, available online at: https://cpcb.nic.in/Actionplan/West%20Bengal.pdf
[228] Oxford Low emission strategy, 2013, p.20, available online at: https://www.oxford.gov.uk/downloads/download/156/low_emission_strategyhttps://www2.oxfordshire.gov.uk/cms/sites/default/files/folders/documents/roadsandtransport/transportpoliciesandplans/localtransportplan/ConnectingOxfordshirevol1policyandoverallstrategy.pdf

Plan,[229] the Local Transport Plan,[230] and the Oxford Area Strategy.[231] This measure also required community engagement, looking for support from the local Low Carbon Hub.[232] The current Oxford Local Plan, LTP4 sets out the proposed transport solutions for the county up to 2031. This includes a Bus Strategy and Rail Strategy to improve the local public transport networks, taking into account projected passenger demand.[233] A new AQAP has also been produced to outline the actions needed to improve air quality in Oxford from 2021 to 2025, with a key objective to bring NO_2 emissions into legal compliance as soon as possible.[234] A priority in the new AQAP which works toward improved public transport infrastructure and service quality is to "*reduce the need to travel, explore opportunities for mode shift and increase the uptake of sustainable transport*". This includes the delivery of sustainable transport measures such as bus priority lanes and cycling improvements.[235]

In Cambridge (UK), the City Access Strategy[236] aims to offer better alternatives to travel by car, boost economic growth and quality of life. For example, encouraging a modal shift to cycling by improving cycle routes and bike parking infrastructure. Increased use of public transport can be encouraged by providing better bus services, such as increasing service frequency, reducing travel times and using smart ticketing to speed up bus journeys and make them more reliable.[237] Alternatively, personal vehicle use can be actively discouraged through use of parking charges or closing some roads to cars. The estimated revenue cost in Greater Cambridge for an improved public transport network is £20 million (approximately IND 2 billion) per year, with the council anticipating a need to double public transport capacity from 2018 to 2031.[238]

Mobility in Hamburg (Germany) has changed significantly in recent years due to loss of the attitude of importance of owning your own vehicle, growing use of public transport, a steadily growing share of cycling, and greater choices of transport types available.[239] The complementary services supporting this demand tend to be digital resources and flexible offers that can be tailored to the users' specific mobility needs. The public transport company HOCHBAHN provides extensive mobility throughout Hamburg: 114 bus routes covering over 920 km and 1,300 bus stops, with greater than 800 vehicles in operation,[240] four metro lines that have been continuously expanded since the first (U3) line in 1912, now totalling over 100 km of track and 93 metro stops,[241] and provision of park & ride and bike & ride services (see Section 4.7.1) at many stops (both operated by HOCHBAHN and by other operators).[242] To enable accessibility, all HOCHBAHN buses are modern low-floor vehicles with low-entry access and lowerable decks, meaning wheelchairs, pushchairs and bicycles can all easily be transported onto the

[229] Air Quality Action Plan 2021-2025, 2021, available online at: https://www.oxford.gov.uk/downloads/file/7428/air_quality_action_plan_2021-2025
[230] Connecting Oxfordshire: Local Transport Plan 2015-2031, 2015, available online at: https://www2.oxfordshire.gov.uk/cms/sites/default/files/folders/documents/roadsandtransport/transportpoliciesandplans/localtransportplan/ConnectingOxfordshirevol1policyandoverallstrategy.pdf
[231] Oxford Core Strategy 2026, 2011, available online at: https://estates.admin.ox.ac.uk/files/oxfordcitycouncilcorestrategy2011-2026pdf
[232] Oxford Low emission strategy, 2013, p.20, available online at: https://www.oxford.gov.uk/downloads/download/156/low_emission_strategy
[233] Connecting Oxfordshire: Local Transport Plan 2015-2031, 2015, p.54, available online at: https://www2.oxfordshire.gov.uk/cms/sites/default/files/folders/documents/roadsandtransport/transportpoliciesandplans/localtransportplan/ConnectingOxfordshirevol1policyandoverallstrategy.pdf
[234] Air Quality Action Plan, 2021, available online at: https://www.oxford.gov.uk/info/20216/air_quality_management/206/air_quality_management_in_oxford/2
[235] Air Quality Action Plan, 2021, p.30, available online at: https://www.oxford.gov.uk/info/20216/air_quality_management/206/air_quality_management_in_oxford/2
[236] City Access, Cambridge, https://www.greatercambridge.org.uk/city-access#:~:text=To%20tackle%20the%20current%20and,better%20choices%20for%20their%20journeys.&text=Greater%20Cambridge%20is%20a%20national%20economic%20success%20story.
[237] Cambridge City Council Air Quality Action Plan 2017 – 2022, 2018, p. 27 available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf
[238] City access and bus service improvements update, Cambridge, available online at: https://scambs.moderngov.co.uk/documents/s108578/7-City%20Access.pdf
[239] Master Plan for Designing More Sustainable and Emission-Free Mobility in Hamburg as part of the Immediate Program for Clean Air 2017 – 2020, 2018, available online at https://www.bmvi.de/SharedDocs/DE/Anlage/K/Masterplaene-Green-City/hamburg.pdf?__blob=publicationFile
[240] The bus network, HOCHBAHN, Hamburg, https://www.hochbahn.de/hochbahn/hamburg/en/home/transport/means_of_transport/bus
[241] The metro system, HOCHBAHN, Hamburg, https://www.hochbahn.de/hochbahn/hamburg/en/home/transport/means_of_transport/metro
[242] Bike and car, HOCHBAHN, Hamburg, https://www.hochbahn.de/hochbahn/hamburg/en/home/transport/means_of_transport/bike_and_car

buses. In metro stations, 80% are wheelchair/pushchair accessible via lift/elevator. Bringing a bike onto metro trains is free of charge, as well as on most of the bus routes, although priority spaces go to wheelchairs and pushchairs so this may not be possible during peak travel times. A key feature of the HOCHBAHN network is residents' involvement.[243] HOCHBAHN has had a designated department for this since 2016, with a representative / point of contact available for each major project at an earlier date than is required by German law. A digital platform has been provided that combines a detailed information hub (covering the current network and planned projects / expansions) with the opportunity for residents to give feedback on the current transport provision and projects.[244] This enables the citizens of Hamburg to access any information they may need to about travelling on the HOCHBAHN network, and also feel included in shaping the future expansions in their city.

Also in Hamburg, Smart Lockers have been installed following an increase in online delivery services that are contributing to busy roads in the city. The company Deutsche Bahn is working together with German start-up ParcelLock on a solution for train travellers who pass a train station every day without going out of their way, and use public transport.[245] Picking up a parcel at a station you travel through already may be preferable to missing a parcel delivered at home, and having to go and collect it from the post office. The process also decreases the number of delivery vehicles on the road, as many parcels can be delivered to one location in one trip. The "Hamburg Box" is similar to technology already provided by the delivery company DHL. The Smart Lockers are locked storage areas that can be unlocked with the free ParcelLock app – this works for dropping off parcels to be returned, or collecting orders. For Deutsche Bahn, this pilot project in Hamburg is another component of the overarching "Smart City" scheme, in which the city and facilities are to be made more modern and functional. There are around 20 train stations with the Smart Lockers installed so far.

Zurich, the capital city of Switzerland, was named the number one city in the European 'Soot Free Cities' 2015 ranking and has found huge success in expanding its public transport network significantly.[246] The city has set public transport as a priority for decades, with consistent promotion and expansion since the 1980s.[247] The city has a comprehensive system with a dense network of stops for the metropolitan rail system, trams and buses. The majority of inhabitants have at least one stop within 300 m of their home or workplace. Even in peak periods, almost every passenger waiting at a stop can find a place on the next tram or bus. Key improvements in availability for passengers have been achieved through larger vehicles, new lines and the extension of existing lines, and increased frequency. In particular, the city has over the years responded to changes in leisure-time needs (e.g. increasing frequency of services later in the evening) and flexible working models. In the five years leading up to the Soot Free cities ranking in 2015, the frequency of public transport modes was increased further, several new tram lines and a new fast S-Bahn (city train) track (the Durchmesserlinie – diameter line) were put into service. A further tram line connecting various parts of the city, along with electrification and extension of two bus lines is planned by 2025. Overall, about €570 million (approximately IND 50 billion) will be spent. The city has established very good information and communication services for its public transport. A further push for the usage of public transport can be expected through the "2000-Watt-Gesellschaft" project (2000-Watt Society, see Section 4.7.8).

[243] Resident involvement, HOCHBAHN, Hamburg, https://www.hochbahn.de/hochbahn/hamburg/en/home/transport/means_of_transport/bus/!ut/p/z1/04_Sj9CPykssy0xPLMnMz0vMAfljo8zizR1NDIw8nA18LELNHQ0Cg03Ng8MMDJw8_Q30w9EUhHm4AhUEWHg6eYcYuYca6EcRo98AB3AkUj8eBVH4jQ_XjwIr8fNwcTb0BJpgYGBsZhDo6W1s7hoYZmhgZgZVgN0KYwtDTAWYYUDIFQW5oaERBpme6Y6KigBIOCXg/?1dmy&urile=wcm%3apath%3a/hochbahn/wcm/connect/en/portal+site/z6_000000000000000000000000a0/z6_7a402hc0l8vhe0qsp8ibkt2gu0/z6_7a402hc0l8u7a0qs57sv003ks0/z6_7a402hc0l8u7a0qs57sv00f577/z6_7a402hc0l8u7a0qs57sv00v2b1

[244] More subway for Hamburg: Have a say!, HOCHBAHN, https://www.schneller-durch-hamburg.de/

[245] Smart Locker, Hamburg, https://www.computerbild.de/artikel/cb-News-Connected-Car-Smart-Locker-Deutsche-Bahn-Hamburg-Box-Paketzustellung-25225553.html

[246] European City Ranking 2015, Best practices for clean air in urban transport, 2015, http://www.sootfreecities.eu/sootfreecities.eu/public/

[247] Urban Traffic Programme "Stadtverkehr 2025", Zurich, 2012, available online at: https://www.stadt-zuerich.ch/content/dam/stzh/ted/Deutsch/stadtverkehr2025/Publikationen_und_Broschueren/Stadtverkehr-Report-2012-en.pdf

As well as improvements in air quality, co-benefits from improved public transport and infrastructure include reduced GHG emissions, reduced travel times, and economic benefits from travel fares.[248] Added value can also come from public transport with new initiatives such as smart lockers, which provide another service alongside the public transport hubs.

4.4.2 Discounted / intermodal tariff offers and networking in public transport

To ensure a multimodal transport system is as accessible for end users as possible, there are a few key actions that can be taken. As many modes of transport as possible should be included under one ticketing and tariff system, making it simpler for travellers to transfer between modes, especially at short notice. Digital sales options (e-ticketing) can be an easy-to-use and time-saving alternative to the classic machine or on-board sales, and may encourage new users to consider public transport. Reasonable pricing and discounts for daily, weekly, monthly, or even annual tickets are likely to increase the use of public transport systems due to value for money and ease of use.

Some of these actions can only be implemented by the public transport operator, which is normally not the city government but an outside company or organisation. This can also cause challenges to intermodal tariff offers because multiple companies may run different modes of public transport, so agreements on ticketing and pricing are more difficult. However, there is an overall benefit to pursuing these agreements because intermodal tariff offers encourage the use of all forms of public transport, and are likely to increase the use of services that are maybe traditionally less busy than other modes of transport.

The city of Reutlingen in Germany aims to implement a 'multimodal mobility focus' by networking the various modes of transport including public transport, bicycle traffic, pedestrian traffic and car sharing, as well as providing further mobility offers and services at selected locations in the city.[249] Existing stops (e.g. bus stops or train stations) as well as future breakpoints will become 'mobility focal points' for all road users. These focal points will make transfer between the different modes of transport easier and may include bicycle parking, bicycle renting / sharing stations, charging stations etc. Offers for car and bike sharing will also be considered. There are two streams of funding available: the Municipal Directive funding may cover up to 50% of the costs, while the Federal competition for climate protection through cycling may cover up to 70% of costs. Exact values have not been provided, but implementation costs are described as 'medium' and running costs 'low'. The estimated impact of these measures is a reduction in private car trips (in domestic traffic) of between 2.5 – 5%.

Hamburg is to host ITS World Congress in October 2021,[250] demonstrating its commitment and success in the field of smart mobility. There are a number of ongoing ITS projects in Hamburg including: Hamburg Electric Autonomous Transportation (HEAT, see Section 4.3.1), Test Course for Automatic and Interconnected Driving (TAVF),[251] the smartphone-based ticketing service Check-In/Be-Out,[252] the mobility platform Switchh,[253] traffic light forecast services (see Section 4.5.1), parking space management (see Section 4.5.4), carpooling/carsharing services (see Section 4.4.8), coordination of construction sites (current construction can be found on the Traffic Hamburg[254] website), a Smart Locker service for commuters (see Section 4.4.1), and infrared cameras on traffic lights for traffic volume assessment (see Section 4.6.2).

With respect to tariff offers, Hamburg's Check-In/Be-Out[255] digital payment system allows for integration of the full public transport system as well as the cheapest fares possible. The user must check in with their smartphone when they board and confirm the station. Once at their destination, the system

[248] Air Pollution Reduction Strategy for Bangladesh, 2012, pp.58 – 63 http://old.doe.gov.bd/publication_images/60_air_pollution__reduction_strategy.pdf
[249] Master plan for the design more sustainable and emission-free mobility, Green City Plan Reutlingen, 2018, available online at: https://www.reutlingen.de/de/Rathaus/Rathaus-Themen/Verkehr-und-Mobilitaet/Green-City
[250] ITS World Congress 2021, https://itsworldcongress.com/?cookie-state-change=1612172941002
[251] Test Course for Automatic and Interconnected Driving, Hamburg, https://www.hamburg.de/contentblob/11622328/72513688c5ae13455f2eff8758f44982/data/teststrecke-tavf.jpg
[252] Check-in/Be-out, Hamburg, https://www.hochbahn.de/hochbahn/hamburg/en/home/projects/expansion_and_projects/cibo
[253] HVV Switchh, Hamburg, https://www.hvv-switch.de/de/inhalt/switchh/
[254] Traffic Hamburg, https://www.hamburg.de/verkehr/
[255] Check-in/Be-out, Hamburg, https://www.hochbahn.de/hochbahn/hamburg/en/home/projects/expansion_and_projects/cibo

automatically checks the user out (this can also be done manually) and calculates the cheapest fare. If a passenger travels several times on the same day then a day pass will be automatically issued. Check-In/Be-Out is one of the anchor projects of the ITS World Congress 2021 and will be presented there.[256] The system will be further optimised and a final version will be created on the basis of the passengers' experience with Check-In/Be-Out; as citizens are able to use a version of the service during summer 2021. The original Switchh mobility platform has joined with HVV (a transport association coordinating public transport in Hamburg) to launch HVV Switchh.[257] The app is linked to Google Maps (allowing the user to plot the exact route and ticket for the route) and covers HVV tickets as well as MOIA[258] shuttles (another lift share service). Single tickets, day passes, group tickets and more are available through HVV Switchh, and tickets are 7% cheaper via the app than if they were purchased at a ticket machine or on the bus. International services such as Liftshare[259] and CarpoolWorld[260] are also available, which provide a ride-sharing facilitation service. A summary of intermodal offers and networking organisations which are available in Hamburg is presented in Table 4 to highlight the types of services available.

Table 4: Summary of intermodal offers and networking in Hamburg, Germany

Logo	Name	Description
MOIA	MOIA	MOIA is a ride-sharing service which allows passengers to request and book rides, currently with a fleet of 330 electric vehicles. [261]
ioki inspiring smart mobility	ioki	Ioki provides mobility analytics solutions, allowing passengers to find the most convenient method of transport to their destination. [262] Ioki is using electric taxis made by London Electric Vehicle Company (LEVC) for its shuttle service in Hamburg.[263]
HEAT	Project HEAT	Hamburg Electric Autonomous Transportation project is trialling the first driverless minibus service in Hamburg public transport. [264]
HVV	HVV and HVV-Switchh	The HVV Switchh App allows passengers to buy tickets and book rides for bus train, subway, ferry and ridesharing such as with MOIA in one place.[265] HVV offers other services including electric scooters[266] and the Check-in/be-out service, which allows passengers to pay the lowest price for their journey. [267]
liftshare travel happy	Liftshare	Liftshare is a UK-based car-sharing system, which is used throughout Europe. The Liftshare App provides a messaging service which allows members to communicate about shared journeys and check journey times. [268]

[256] Check-In/Be-Out, HVV, Hamburg, https://www.hvv.de/de/ueber-uns/aufgaben-und-projekte/check-in-be-out
[257] HVV Switchh, Hamburg, https://www.hvv-switch.de/de/inhalt/switchh/
[258] MOIA Hamburg, https://www.moia.io/en/hamburg
[259] The Liftshare story, 2021, available online at: https://business.liftshare.com/about-us/
[260] Free Carpool Listings and Rideshare Software, 2021, available online at: https://www.carpoolworld.com/carpool_ride.html
[261] The MOIA fleet in Hamburg, 2021, available online at: https://www.moia.io/de-DE/hamburg
[262] Operating system for digital mobility, available online at: https://ioki.com/en/operating-system/
[263] Hamburg: Deutsche Bahn to use LEVC electric cabs, 2018, available online at: https://www.electrive.com/2018/07/18/hamburg-deutsche-bahn-using-electric-cabs-of-levc/
[264] The future is driverless, 2021, available online at: https://www.hochbahn.de/hochbahn/hamburg/en/home/projects/expansion_and_projects/project_heat
[265] And what about switchh?, 2021, available online at: https://www.hvv-switch.de/de/inhalt/switchh/
[266] Electromobile (E-Scooter), 2021, available online at: https://www.hvv.de/de/service/fragen-und-antworten/elektromobil-e-scooter-
[267] Check-in / be-out, available online at: https://www.hvv.de/de/ueber-uns/aufgaben-und-projekte/check-in-be-out
[268] The Liftshare story, 2021, available online at: https://business.liftshare.com/about-us/

Logo	Name	Description
	CarpoolWorld	CarpoolWorld is an App which allows passengers to connect with rideshare partners and make arrangements to share journeys. [269]

Discounted and intermodal tariff offers can benefit both the public transport operators and the users. Intermodal tariff offers encourage the use of all forms of public transport, and are likely to increase the use of services that are usually less popular than other modes of transport. Discounts and tariff offers benefit the users in more than one way. They may make their journey much easier, if they are able to use a form of public transport that gets them closer to their start/end point – this can also increase safety of travellers, especially at night. Reduced costs of public transport may cause citizens to use their car less or get rid of it altogether, which can save them a considerable amount of money.

4.4.3 Cycle network

A strong cycle network creates good foundations for a culture of safe and comfortable cycling. A cycle network should be complemented by secure cycle parking facilities in the city centre and at key transport hubs. Secure and reliable locations to park bikes and other alternative transport equipment are vital to help citizens overcome any concerns in the uptake of an active travel option. Improved cycling networks will enable cycling to become a viable option for travelling to work or school, or even for leisure.

A city's cycle network may consist of cycle-only routes, as well as shared spaces between cyclists and motor vehicles, and cyclists and pedestrians. In all cases, it is important that the routes have good quality surfaces, clear signage, and are safe for all users. Creating a completely new network, or expanding a cycle network is likely to require a significant amount of investment from the city.

The Cambridge (UK) AQAP considers the local cycling and walking infrastructure plans,[270] which show that planning policies should provide high quality walking and cycling routes, as well as parking facilities to encourage modal shift to cycling. Development of a new and/or improved network of cycle routes, both within and between neighbourhoods, is being developed by the City Access team.[271,272] This can be achieved by mapping the main sites of attraction around the city to which people are likely to travel, such as key employment sites, tourist attractions, and retail parks. Using this information, the most useful links between points can be assessed and ideal positions for expanded or improved cycle routes can be developed using a route selection tool (RST).[273] Schemes and grants have been made available to encourage cycling, such as the 'Cross City Cycling' scheme, which aims to improve walking and cycling links to schools and employment centres.

Cycling conditions in the city of Mannheim in Germany are ideal, according to the 'Sustainable Mobility for the City' Green City Plan.[274] Located on the Rhine, the city has a temperate climate all year round and is flat and compact. Approximately one third of Mannheim's population lives within 5 km of the city centre, similar to Cuttack and Bhubaneswar which are both described as compact cities in their respective air quality plans;[275] the average daily trip in Bhubaneswar is shorter than 5.5 km.[276] The cycle network in Mannheim spanned 293 km as of 2018; of the (greater than) 800 km road network, 470 km

[269] Free Carpool Listings and Rideshare Software, 2021, available online at: https://www.carpoolworld.com/carpool_ride.html
[270] Peterborough City Council Local Cycling and Walking Infrastructure Plan 2019-2029, 2019, available online at: https://www.peterborough.gov.uk/asset-library/PCC-LCWIP.pdf
[271] City Council Air Quality Action Plan 2018 – 2023, 2019, p.51-78, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf
[272] City Access (2019), available online at: https://www.greatercambridge.org.uk/city-access
[273] Peterborough City Council Local Cycling and Walking Infrastructure Plan 2019-2029, 2019, p.11-19, available online at: https://www.peterborough.gov.uk/asset-library/PCC-LCWIP.pdf
[274] Master plan "Sustainable Mobility for the City", Green City Plan, Immediate program for clean air 2017 – 2020, Heidelberg, Ludwigshafen and Mannheim, 2018, available online at: https://www.bmvi.de/SharedDocs/DE/Anlage/K/Masterplaene-Green-City/heidelberg-ludwigshafen-mannheim.pdf?__blob=publicationFile
[275] Comprehensive Action Plan for Clean Air for Non-Attainment Cities of Odisha, Air Quality Monitoring Committee, Government of Odisha – Cuttack, 2018.
[276] Comprehensive Action Plan for Clean Air for Non-Attainment Cities of Odisha, Air Quality Monitoring Committee, Government of Odisha – Bhubaneswar, 2018.

of this is traffic-calmed in a way that is suitable for cycling. Mannheim launched a '21-point program' to increase the share of cycling, in 2010. Actions included closing 32 gaps in the cycle network on main roads, improving the cycling infrastructure and promotion of cycling. These actions led Mannheim to increase the share of cycling by 5% by 2013, and to be named as a "bicycle-friendly municipality" by the state of Baden-Württemberg in 2017. By 2020, the city aimed to increase the share of cycling by a further 5%, to 23% of domestic traffic.

In recent years in Zurich, Switzerland, individual infrastructure measures designed especially for bicycle traffic have been implemented. The Bicycle Master Plan[277] provides for the realisation of a continuous basic network of primary routes and comfort routes that supplement each other. The primary routes enable direct travel with a bicycle across the city, while the comfort routes provide safe travel for those with less practice or for more leisurely use, such as families with children. In 2012, 45 km in the primary route network and 29 km in the comfort route network met the quality requirements defined in the Bicycle Master Plan: by 2025 the intent is to have all sections in the network of primary routes and comfort routes at least at Quality Level B, with as much as possible at Quality Level A (the highest level). Further measures to improve bicycle traffic include implementation of various additional, continuous bicycle paths, and making existing bicycle routes more visible with signs and markings. The estimated cost of additional infrastructure in the Bicycle Master Plan is CHF (Swiss Franc) 55 million (approximately IND 4.5 billion), not including any costs for bike hiring or bicycle stations.

Co-benefits from improving cycling infrastructure include reduced congestion, improved air quality, improved cyclist safety (and fewer road accidents), increased uptake of active travel modes and improved health and fitness of citizens.[278,279]

4.4.4 Priority bicycle routes / junctions

As well as a strong cycling network from which to begin, the interaction of cyclists with motor vehicles is a key factor when it comes to bicycle usage. Often, the most dangerous time for cyclists on the roads is not within moving traffic, but at junctions or traffic lights. Therefore, measures to protect cyclists during these times are important. Making cyclists feel safe, and feel like a priority in the city, is important to encouraging uptake of cycling.

This measure links in with the cycle network (see Section 4.4.3) and there are many actions that can prioritise cyclists when travelling in the city. These include, but are not limited to:

- Cycle-only lanes (near to or away from motor traffic);
- Designated areas within traffic lanes and at junctions for cyclists;
- Safe, secure areas to park bicycles (including at bus and train stations, at workplaces and shopping centres);
- The ability to take bicycles onto public transport free of charge; and
- Priority green lights for cyclists at traffic lights.

The city of Herrenberg 'Master plan Green plan'[280] noted that the share of cycling in Herrenberg (Germany) had been relatively constant for years and was not increasing. The plan looked at survey results from the 'Handbook for cycling in the municipality' (Handbuch Radverkehr in der Kommune) to get an idea of the composition of potential cyclists in Herrenberg. The survey found that just 5% of those who answered were permanent cycle users and 2% considered themselves 'fearless' when it came to cycling. Approximately one third (33%) of those who answered stated they could not be won over to cycling because they refuse to ride, or cannot cycle due to handicaps. The remainder, 60%, would cycle if it were safer and they felt comfortable – meaning approximately two thirds of the population could potentially be 'won over' to cycling. Herrenberg then looked at countries with large proportions of the population that cycle, including the 'Bicycle traffic planning from A to Z, The Dutch planning handbook

[277] Master plan and construction program Velo, Zurich, https://www.stadt-zuerich.ch/ted/de/index/stadtverkehr2025/masterplan_velo.html
[278] Peterborough City Council Local Cycling and Walking Infrastructure Plan 2019-2029, 2019, p.21, available online at: https://www.peterborough.gov.uk/asset-library/PCC-LCWIP.pdf
[279] Cross City Cycling, Cambridge, https://www.greatercambridge.org.uk/transport/transport-projects/cross-city-cycling
[280] City of Herrenberg, Master plan Green plan, Measures to reduce nitrogen oxide pollution from traffic, 2018, available online at: https://www.bmvi.de/SharedDocs/DE/Anlage/K/Masterplaene-Green-City/herrenberg.pdf?__blob=publicationFile

for bicycle-friendly infrastructure'. They determined that cycle paths should be essentially independent from the road traffic network; continuously usable and recognisable; sufficiently wide; barrier-free; and cyclists should have equal rights or even priority at junctions. In essence, the cycle paths should be safe, comfortable, fast, direct, and a pleasant environment. Herrenberg's cycle paths did not meet this brief, and the Master plan Green plan set out new planning for cycling in the city to resolve this. A particular target is to ensure that more vulnerable cyclists (such as schoolchildren, the elderly, and less experienced cyclists) are safe when using the cycling network, and feel confident to use it.

In Berlin, the capital city of Germany, there are a number of measures that demonstrate that cyclists are a priority when travelling in the city. Only one in three people in Berlin has a car, but almost everyone has a bicycle, and the Berlin Senate pledged to invest over €30 million (approximately IND 2.6 billion) in modern cycling infrastructure in 2020 (compared to just under €5 million (approximately IND 439 million) in 2016).[281] At the end of 2016, there were only a handful of people responsible for cycling in Berlin's administrative authorities, however, in 2020 there were around 60 employees improving cycling matters in the Senate, the municipal infraVelo company, and in the city's districts. There are an increasing number of protected bike lanes that separate cyclists from automobile traffic and allow people to move around on two wheels without hindrance – for example, on the Hasenheide and Holzmarktstrasse. Green cycle lanes help to improve safety with their visibility; they can be quickly implemented and demonstrate the increased importance of cycling in Berlin. The Senate has also funded around 15,000 new bike stands in Berlin's districts since 2017, providing more space for people to park their bicycles without fear that they will be damaged or stolen. Thousands more are set to be installed in the future, together with bike-parks and secure parking at underground and suburban train stations.

General co-benefits from uptake of cycling include reduced congestion, improved air quality, increased uptake of active travel modes and improved health of citizens. In particular, showing that cyclists are a priority in the city will make cyclists feel safe and valued, and is likely to further increase the uptake of cycling.

4.4.5 Footpath network

Improved footpath networks will enable walking to become a viable option for travelling to work or school, and encourage walking for leisure. Cuttack and Bhubaneswar are both described as compact cities in their respective air quality plans[282] and the average daily trip in Bhubaneswar is reported to be shorter than 5.5 km.[283] The likelihood is that many daily trips to work or school are considerably shorter than that, meaning walking could be an option. There are several aspects of a footpath network that need to be considered in order to make it appealing to the general population:

- Footpaths should be wide enough for overtaking, or passing those going in the opposite direction;
- They should have a smooth surface that is easy to walk on, but does not become slippery when wet or icy;
- Roads and other obstacles should be easy to cross – for example pedestrian crossings with short waiting times;
- Pedestrians should be separate from bicycle traffic, as well as motor traffic;
- Noise pollution, odours and air pollution should be minimised for an attractive and healthy experience;
- Depending on the climate, there may be requirements for shade and/or shelter as well as places to rest (e.g. benches); and
- Footpaths should feel safe – be constant (no gaps where one has to walk in the road), be well lit, away from roadsides and sharp drops, and may have barriers in place to protect users.

[281] Cycling, Berlin, https://www.berlin.de/sen/uvk/en/traffic/transport-planning/cycling/
[282] Comprehensive Action Plan for Clean Air for Non-Attainment Cities of Odisha, Air Quality Monitoring Committee, Government of Odisha – Cuttack, 2018.
[283] Comprehensive Action Plan for Clean Air for Non-Attainment Cities of Odisha, Air Quality Monitoring Committee, Government of Odisha – Bhubaneswar, 2018.

As with cycle networks, a footpath network may consist of pedestrian-only routes, as well as shared spaces between pedestrians and motor vehicles, and pedestrians and cyclists. Footpaths need to be high quality, as described above. Creating new footpaths of a high quality is likely to require a significant amount of investment from the city.

Cambridge, in the UK, aims to promote walking by improving footpath facilities, for instance through re-prioritisation of road space.[284] Walking is promoted under the Travel for Cambridgeshire (TfC) scheme, whose actions include working in partnership with various shops in the City to provide discounted walking and running shoes for the public.[285] Using a similar method to cycle network planning (see Section 4.4.3), walking networks can be developed by mapping key trips in the city and using the data to define the best places to expand or improve routes, taking into consideration barriers and funnels along the routes. A walking route audit tool (WRAT) can be used to assess the suitability of potential routes based on conditions such as directness, safety, and attractiveness.

The city of Zurich in Switzerland designs their footpaths to be direct, safe, and attractive and be usable wherever possible with walking aids or prams.[286] ZüriPlan covers walking and cycling routes and has been available online[287] and via an app since 2016 (see section 4.7.3). A significant number of city walks are also available to download for free online via “Zurich on foot”. Pedestrian infrastructure is constantly being expanded, as described in the Urban Traffic Programme “Stadtverkehr 2025”. The focus of expansion is on closing gaps in the footpath network, and introduction of crosswalks so that pedestrians can safely navigate roads when necessary. The city is also developing a number of new meeting areas where citizens can meet up and spend leisure time; the target locations for these meeting areas are neighbourhood centres, city squares and near to bus / train stations. Zurich was aiming for an 26% share of cycling in the city by 2020, up from approximately 10% in 2012.[288]

Co-benefits from development of walking routes include improved safety, improved uptake of active travel, health benefits (mental and physical) and reduced traffic congestion.[289]

4.4.6 Municipal mobility management

Municipal vehicle fleets may cover large distances in cities and can therefore be a significant source of air pollution. Often, they have a large share in heavy vehicles and diesel engines (such as waste collection, street cleaning, etc.). In addition, to further the cause of alternative transport, municipal fleets should serve as role models for the city’s inhabitants.

When upgrading the municipal fleet, the quantity and types of vehicles should be considered. An initial measure may even be to reduce the fleet size, and this could provide funds to upgrade the remainder of the fleet. The most polluting vehicles should be the focus of upgrades where possible, as well as the vehicles that travel the greatest distances. Alongside vehicle upgrades, the municipal fleet of workers should be provided with alternative forms of transport for meetings and commuting, as well as being encouraged to set an example by walking or cycling.

Cambridge in the UK has produced a City Council Transport Plan[290] that contains measures aiming to enable sustainable travel choices, including public transport discounts through use of travel passes, bicycle training and provision of pool bikes and car sharing schemes. The ‘Travel for Cambridgeshire’

[284] Cambridge City Council Air Quality Action Plan 2018 – 2023, 2019, p.51-78, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf
[285] t4c discounts leaflet, Cambridge, https://www.environment.admin.cam.ac.uk/files/travel_discounts.pdf
[286] Zurich on foot – city walks, https://www.stadt-zuerich.ch/ted/de/index/stadtverkehr2025/routen/city_walks.html
[287] ZüriPlan, https://www.stadt-zuerich.ch/stadtplan
[288] Urban Traffic Programme “Stadtverkehr 2025”, Zurich, 2012, available online at: https://www.stadt-zuerich.ch/content/dam/stzh/ted/Deutsch/stadtverkehr2025/Publikationen_und_Broschueren/Stadtverkehr-Report-2012-en.pdf
[289] Peterborough City Council Local Cycling and Walking Infrastructure Plan 2019-2029, 2019, p.27-28, available online at: https://www.peterborough.gov.uk/asset-library/PCC-LCWIP.pdf
[290] Cambridgeshire Local Transport Plan 2011-2031, 2015, available online at: https://www.cambridgeshire.gov.uk/asset-library/imported-assets/The_Local_Transport_Plan_3%20(1).pdf

scheme aims to promote travel alternatives, for example by offering tools and resources to employers in order to support sustainable travel choices of staff[291] and offering a 10% discount on rail fairs.[292]

Zurich, the capital city of Switzerland, was named the number one city in the European 'Soot Free Cities' 2015 ranking.[293] A category the city scored particularly high in was 'public procurement clean cars' which encompasses measures such as retrofitting existing vehicles, acquiring new cleaner vehicles, reducing the vehicle fleet and investing in alternative energy sources. The municipal authorities in Zurich use carpooling and carsharing facilities for business trips, and for local trips there are bicycles provided. The Federal Office of the Environment (FOEN) took part in Energie Schweiz's New Ride[294] program to support the launch of electric two-wheelers in Switzerland.[295] A network of municipalities, manufacturers, importers, and dealers has been built up, and part of the program enabled consumers to test the electric bikes free of charge.

Sweden's capital city, Stockholm, achieved fourth position in the European 'Soot Free Cities' 2015 ranking.[296] The City's own vehicle fleet consists of 100% alternative fuel vehicles where this possibility is available; in 2014, approximately 9% of the fleet was electric, and by 2016, 98% of the fleet of 800 cars were classed as 'environmental vehicles' under the Swedish national definition.[297] Some exceptions have had to be made, such as some emergency vehicles and the lake ice-plough used to clear snow for skaters. Stockholm has set a goal to increase the portion of electrical vehicles by 2% a year. The car fleet as of 2016 consisted of:

- Petrol - 2.5%
- Diesel - 5.8%
- Plug-in hybrids - 7.3%
- Electrical / fuel hybrids - 9.8%
- Electric vehicles - 11.2%
- Ethanol fuelled - 16.9%
- Gas fuelled - 44.2%

The City of Stockholm is purchasing fewer new cars and encouraging employees to walk, cycle, use public transport, or carpool. Thanks to the initiative, the city has been able to reduce the amount of cars in the fleet by 400 vehicles, since 2007.

Upgrading the municipal fleet to alternative fuel vehicles, as well as encouraging use of other modes of transport, may be a significant investment for the government or council; however, it can be cost-beneficial in the long term due to the aforementioned co-benefits of EVs (e.g. lower fuel and maintenance costs). In addition, municipal fleets should serve as a role model for the city's inhabitants and this can generate good publicity for the government and/or councils, as well as for low emission transport in general.

4.4.7 Corporate mobility management

Corporate mobility management encompasses both the mobility whilst at work (including travel to and from meetings, and a company's fleet of vehicles) as well as how employees commute to and from work.

[291] Cambridge City Council Air Quality Action Plan 2018 – 2023, 2019, p.26, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf
[292] Travel for Cambridgeshire discounts, https://www.greatnorthernrail.com/tickets/discounts-and-railcards/travel-for-cambridgeshire
[293] European City Ranking 2015, Best practices for clean air in urban transport, 2015, http://www.sootfreecities.eu/sootfreecities.eu/public/
[294] New Ride, Zurich, https://www.newride.ch/
[295] Emissions regulations for motor vehicles in Zurich, https://www.bafu.admin.ch/bafu/de/home/themen/luft/fachinformationen/massnahmen-zur-luftreinhaltung/massnahmen-zur-luftreinhaltung-beim-strassenverkehr.html
[296] European City Ranking 2015, Best practices for clean air in urban transport, 2015, http://www.sootfreecities.eu/sootfreecities.eu/public/
[297] The Green Car Fleet of Stockholm City is on Descent – Making the City More Sustainable, https://www.tellusthinktank.com/featuredarticle/the-green-car-fleet-of-stockholm-city-is-on-descent-making-the-city-more-sustainable-no017/

When considering the company's own fleet of vehicles and travel during the working day, the considerations should be similar to municipal mobility management – i.e. first consider the quantity and types of vehicles in the current fleet. An initial measure may be to reduce the fleet size, or to replace the most polluting vehicles first. Unlike with municipal fleets, a corporate fleet may have smaller vehicles in general (instead of HGVs, such as waste management vehicles) so there are different options for replacement, such as e-bikes and e-scooters. Regarding commuter transport, there are many ways to incentivise alternative forms of transport to the private car. Reducing the number of parking spaces available, or charging employees to use parking facilities, is one method, but should be complemented by flexible options for public transport, carsharing, carpooling and cycling. An increasingly popular method of increasing commuting via alternative transport is an employee 'mobility budget' which is described below. Finally, employers can incentivise uptake of EVs by providing (free) EV charging facilities at work.

In Reutlingen in Germany, operational mobility management is to be implemented at Reutlingen-based companies in cooperation with the IHK (the Association of German Chambers of Industry and Commerce) and other local stakeholders.[298] The pilot project for this will be Robert Bosch GmbH, which has multiple locations in Reutlingen as well in the cross-community technology and business park at Kusterdingen (close to Reutlingen) that houses over 8,000 employees. Measures are also planned in the area of communal mobility management, including to promote the use of bicycles by employees.

Daimler Financial Services AG operates in a number of cities in Germany, and is in partnership with the car sharing scheme 'Car2go' in Hamburg (see Section 4.4.8). The company is a great example of corporate mobility management across multiple locations including Stuttgart, Sindelfingen, Berlin and Hamburg.[299] Two of the schemes Daimler uses are a 'dating app for ridesharing', flinc,[300] and a mobility app, REACH NOW.[301] The flinc app matches commuter profiles based on routes and travelling time, so that the most compatible commuting colleagues can be matched and create their own commuter network. At the Mercedes-Benz plant in Sindelfingen, approximately 12,000 employees registered for the flinc app between February 2019 and February 2020, and an estimated 3.3 million km of car travel and 750 tonnes of CO_2 emissions has been avoided in that 12-month period. The use of the REACH NOW mobility app falls under 'mobility budgets' which are becoming more popular in companies, especially in Germany. Employee mobility budgets involve employees receiving time-limited, flexible digital credit for their commute to and from work. The credit can be used on a variety of transport options including bus, train, taxi, carshare or carpool; this is reported to be most useful in urban locations, especially cities where there are more mobility options and often better public transport. The pilot project at Daimler has seen approximately 3,000 employees sign up to REACH NOW in Berlin and Hamburg, among other cities.

A major co-benefit of corporate mobility management is that it can make working for that company much more attractive, especially with the use of employee mobility budgets, and therefore the top talent has more reasons to choose to work for that company over another one. Aside from being given budget to fund their commute, it is beneficial for employees to have a range of commuting options they may not have considered without the budget, and they can also feel they are contributing to 'doing their bit' for the environment. Flexible commuting options and mobility budgets enable those who may have barriers to commuting (e.g. a shared car, no car at all, limited public transport options) to more easily get to and from work. It is also beneficial to the image of a company if it is seen to be reducing their impact on the environment, no matter which field the company is in.

4.4.8 Car sharing

Car sharing services are similar to a taxi or PHV, with the difference being that the car is either hired, or you are sharing with someone who is travelling to the same / similar destination as you. This measure

[298] Master plan for the design more sustainable and emission-free mobility, Green City Plan Reutlingen, 2018, available online at: https://www.reutlingen.de/de/Rathaus/Rathaus-Themen/Verkehr-und-Mobilitaet/Green-City
[299] Corporate mobility management: How Daimler employees get to work, https://www.daimler.com/magazine/mobility/corporate-mobility-management-commuters.html
[300] flinc, https://www.flinc.org/
[301] REACH NOW, https://www.reach-now.com/reachnow-app/

reduces the number of car vehicle trips made and can also lessen pressures on parking in residential areas, workplaces, shopping centres and tourist sites.

There are two main mechanisms for implementation. The first is a car sharing scheme that relies on people who do own a private vehicle taking additional passengers to or near to their own destination. The driver may charge a small fee, especially if the start or end point of the passenger is not the same as the start/end point of the driver. These types of schemes tend to be set up online or via an app, and it is important that users are identifiable, for safety. The second mechanism is essentially a car rental scheme, where users can pick up a car from a designated point and return it later. This method still removes a number of private vehicles from the road, as the user likely doesn't own their own car. However, it may be the case that they don't 'share' their trip with anyone else.

Carsharing is included in Cambridge's (UK) AQAP, with a car and lift sharing group called 'Camshare'[302] forming part of the Travel for Cambridgeshire scheme. This is part of the 'Liftshare' network[303] and provides an alternative to private vehicle use by connecting drivers who want to reach the same destination to share their journey, providing several benefits such as cost and fuel savings, reduced CO_2 emissions and improved air quality.[304]

Reutlingen in Germany provides a car sharing service through TeilAuto.[305] It is recommended that if a person drives less than approximately 7,000 km per year, car sharing is likely to save you money.[306] There are 17 different vehicles available for car share in Reutlingen, that can cater to needs from a small 'run-around' car to a seven-seater vehicle. The TeilAuto website provides locations where users can pick up the vehicles, and users can register online or at the Mobility Centre in the city. TeilAuto is available in 237 cities and municipalities, including Reutlingen.

Car2go[307] is a car sharing fleet that operates in the city of Hamburg Germany (also referred to as SHARE NOW). In 2017, the company had a fleet of 400 smart cars in the city's Home Area (car share area, which includes the city and all the way out to Hamburg Airport), which were to be electrified by the end of 2019 as part of a partnership with Daimler Financial Services AG,[308] and the BMW i3 is also an EV.[309] Other non-electric cars are available, bringing the car sharing fleet to over 1500 vehicles. Car sharing has been integrated into the city's mobility app, Switchh,[310] which is linked to Hamburg's transport authority (see Section 4.4.2).

Car sharing can be financially beneficial for those who do not require a car to commute, but do sometimes require a private vehicle. It can also be a sensible alternative to owning a second vehicle – this may help with fuel, tax, insurance, and maintenance costs, as well as parking space.

4.4.9 Bike rental

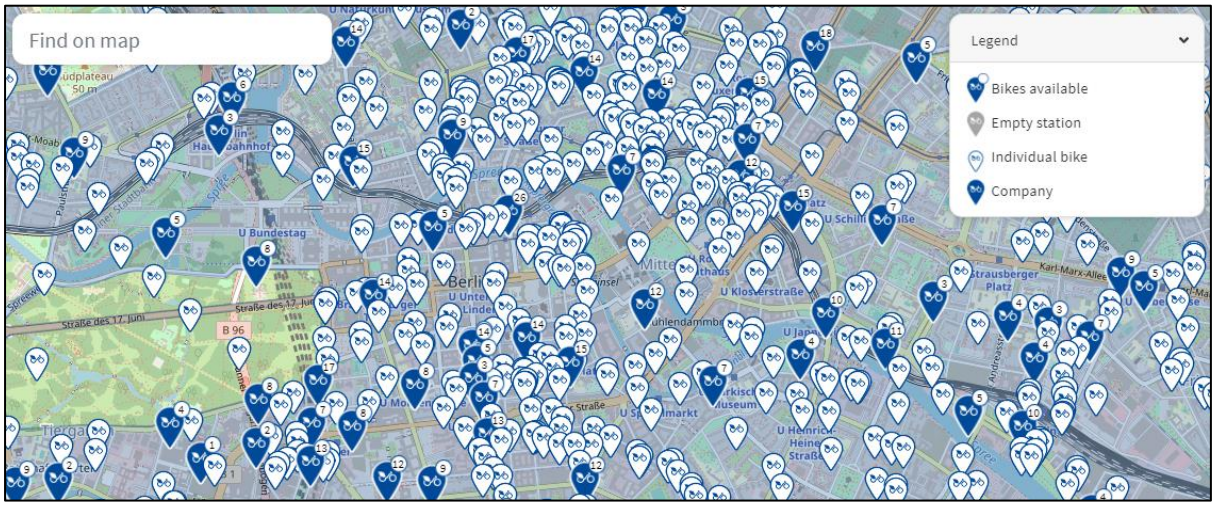
Bike rental schemes are vital in encouraging the population who might not be able to afford to purchase a bicycle to take a more active form of transport. They are also a good way to encourage tourists to see more of a city without taking a taxi or using public transport.

To be viable, bike rental schemes must be well organised. There should be a sufficient number of bike stations (pick up and drop off points) to ensure that bicycles are not discarded in random locations all over the city. The bikes should be fitted with GPS so that they can be located (either for the user, or for the bike rental company) and a dedicated maintenance team must keep the bikes running smoothly. Bikes must be kept at a good standard to minimise the risk of accidents, and provide a good service.

[302] Cambridge City Council Air Quality Action Plan 2018 - 2023 (2019), p.51-76, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf
[303] CamShare (2020), available online at: https://liftshare.com/uk/community/camshare
[304] CamShare (2020), available online at: https://liftshare.com/uk/community/camshare
[305] TeilAuto, Reutlingen, https://www.teilauto-neckar-alb.de/darum-carsharing/
[306] Car sharing, Reutlingen, https://www.reutlingen.de/19792
[307] Car2go Hamburg, https://www.share-now.com/de/en/hamburg/
[308] Daimler and Hamburg sign a pact for urban mobility, https://www.auto-medienportal.net/artikel/detail/40175
[309] New urban mobility measures planned in Hamburg (Germany), https://www.eltis.org/discover/news/new-urban-mobility-measures-planned-hamburg-germany
[310] Switchh,

The Nextbike bike rental system operates in the city of Berlin, Germany.[311] The scheme has been built up since 2017 with support from the Berlin Senate. The current fleet has around 2,500 bikes in the city. The cost to use the service is incredibly affordable, at €1 per 30 minutes (approximately IND 90), and billing occurs at 30 minute intervals.[312] Alternatively, a bicycle can be rented for 24 hours for €15 (approximately IND 1,300). Students of cooperating unis and colleges get up to 30 minutes for free. The bikes are made in Germany, and maintained by the Nextbike service teams daily. Nextbike is also promoting its services for 'last mile' travel – bikes can be rented via a VBB public transport card, as well as the Nextbike app. An example map of Nextbike stations in Figure 12 shows the quantity of bikes available in Berlin city centre.

Figure 12: Map of Nextbike station locations in Berlin, Germany[313]



Copenhagen (Denmark) has a public bike sharing scheme called 'Bycyklen' (The City Bike), named after a specially designed city bike called 'City Bike One' presented to the city of Copenhagen as a gift from American president Bill Clinton on a visit in 1997.[314] The Bycyklen bikes are available all over the city and are made to be easy to use, as well as accessible via an adjustable seat. The bikes are e-bikes that are available 24 hours per day, 365 days a year. Each bike has a touchscreen tablet which can be used for navigation, payment, and guidance to points of interest in Copenhagen and Frederiksberg. To use the bikes, a user account must be created, which can be done online[315] or directly on the bike tablet (located on the handlebars). The only requirements are name, email address, telephone number, and payment information. There are over 100 Bycyklen stations around the city, where bikes can be collected from and returned to.

The co-benefits of bike rental schemes are mainly health benefits from uptake of active travel, although they also reduce GHG emissions as well as air pollution by decreasing trips via private vehicle. Bike rental companies may be able to provide additional financial support in the development of cycle networks and associated facilities.

[311] Cycling, Berlin, https://www.berlin.de/sen/uvk/en/traffic/transport-planning/cycling/
[312] Nextbike, https://www.nextbike.de/en/berlin/
[313] Locations, https://www.nextbike.de/en/berlin/locations/
[314] Bycyklen, Copenhagen, https://www.visitcopenhagen.com/copenhagen/planning/bycyklen-gdk495345
[315] Bycyklen, Copenhagen, https://bycyklen.dk/

4.4.10 Evaluation of mode shift measures

The mode shift measures described above have been evaluated according to the criteria outlined in Section 4. Table 5 provides a summary of the results.

Table 5: Evaluation of mode shift measures

Measure	Which pollutants are impacted?	Evaluation according to criteria					
		Air quality impact (1-5)	Costs (1-5)	Co-benefits (1-5)	Reliance on other measures (1-5)	Innovation (1-5)	Prospective timescale (1-5)
Public transport infrastructure and service quality	**NOx, PM**	✓✓✓	✓✓✓✓	✓✓✓✓✓	✓✓	✓✓✓	✓✓
Discounted / intermodal tariff offers and networking in public transport	**NOx, PM**	✓✓✓	✓✓✓✓	✓✓✓✓✓	✓	✓✓✓✓	✓✓✓✓
Cycle network	**NOx, PM**	✓✓	✓✓✓✓	✓✓✓✓✓	✓✓	✓✓	✓✓✓
Priority bicycle routes / junctions	**NOx, PM**	✓✓	✓✓✓	✓✓✓✓✓	✓✓	✓✓✓✓	✓✓✓
Footpath network	**NOx, PM**	✓✓	✓✓✓	✓✓✓✓✓	✓✓	✓✓	✓✓✓
Municipal mobility management	**NOx, PM**	✓✓	✓✓✓✓	✓✓✓✓	✓	✓✓✓✓	✓✓✓✓
Corporate mobility management	**NOx, PM**	✓✓	✓✓✓	✓✓✓	✓	✓✓✓✓	✓✓✓
Car sharing	**NOx, PM**	✓✓	✓✓	✓✓✓✓	✓✓	✓✓✓✓	✓✓✓✓
Bike rental	**NOx, PM**	✓✓	✓✓✓	✓✓✓✓	✓✓	✓✓✓✓	✓✓✓✓✓

4.5 Transport and urban planning

4.5.1 Dynamic traffic management

Dynamic traffic management is a broad measure that can cover many actions and therefore be tailored to the needs, and the capabilities, of the city. The overall aim of dynamic traffic management is to achieve a smooth flow of traffic and react to events such as pollution hotspots, congestion, or accidents. A smoother flow of traffic is less polluting than stop-start traffic, or idling traffic, meaning pollutant concentrations decrease. More information can also be found in Section 4.5.5.

Dynamic traffic management could be implemented via a number of different actions, or combinations of actions, including:

- Directing traffic away from pollution hotspots, especially at peak traffic times.
- Digital information and guidance systems on major roads in and around the city (such as ring roads or motorways) providing the least congested or fastest routes at that time.
- Signage on roads where use of GPS devices / apps is not recommended.
- Signage to show where park & ride could be used instead of driving into the city.
- Optimisation of traffic light systems to smooth traffic flows.

The Comprehensive Air Quality Action Plan for Kolkata, India, includes proposed measures to remove congestion from densely populated/most frequented road stretches through traffic re-engineering.[316] This measure includes the development of an integrated automated network system of traffic light signals, whereby traffic light systems are automated and upgraded, reducing congestion, and improving traffic flow. Traffic signals may also be replaced with circular roundabouts to aid the removal of congestion from densely populated / most frequented road stretches (see Section 4.5.5). Another related action under the measure is the introduction of SCADA (Supervisory Control And Data Acquisition) software to provide better monitoring and control of traffic management, which aims to provide drivers with a faster, safer trip on roads. Smart Variable Message Signs (VMS) can also be introduced. These are digital road signs which are used by Kolkata police to inform car drivers about specific temporary events and real-time traffic conditions. This can be further developed by introducing an early alarm system during traffic congestion for the benefit of commuters on major routes, to facilitate route diversion and synchronise traffic movements.

The city of Reutlingen in Germany has had a number of methods of digitally influencing traffic for many years. A traffic computer with a software system for adaptive control of traffic networks (INES) has been in place since 2007 to control traffic flows; the current (as of their 2018 “Master plan for the design more sustainable and emission-free mobility”[317]) method sets a higher or lower circulation of traffic depending on the traffic levels at the time. The network computer accesses traffic data from the roads via detection loops (also referred to as ‘strategy looks’ or induction strips), counting vehicles and measuring their speed. The information is used to calculate vehicle numbers and travel times. In-flow metering limits traffic at two pollutant hotspot locations in Reutlingen, reducing traffic levels when necessary so that the traffic light system can stabilise traffic flows again. Aside from reacting to current situations, planned disruptions such as construction works, special transports and key events are loaded into the network computer to allow planning for these situations in advance. Going forward, Reutlingen aspires to include environmental data into INES (including temperature, weather, and pollution levels) and also review and adapt the existing traffic light programs to make them more efficient. As the systems are already in place, the running and maintenance costs are low.

Berlin, the capital city of Germany, has one of the largest state-of-the-art traffic control centres (Verkehrsregelungszentrale, VKRZ) in Europe.[318] The traffic control centre is responsible for monitoring and manually activating traffic light systems at approximately 2,000 intersections in Berlin, for operating nine Variable Message Sign (VMS) systems on the Berlin motorways, for monitoring the traffic situation

[316] Comprehensive Air Quality Action Plan for Kolkata, 2018, p. 11, available online at: https://cpcb.nic.in/Actionplan/West%20Bengal.pdf
[317] Master plan for the design more sustainable and emission-free mobility, Green City Plan Reutlingen, 2018, available online at: https://www.reutlingen.de/de/Rathaus/Rathaus-Themen/Verkehr-und-Mobilitaet/Green-City
[318] Traffic Control Centre (VKRZ), Berlin, https://www.berlin.de/sen/uvk/en/traffic/traffic-management/traffic-control-centre/

on over 1,500 km of roads, and for transmitting traffic information from the regional reporting office (known as TMC procedure). By collecting all traffic information in one place, the Berlin Traffic Management is able to directly influence the traffic situation in and around Berlin and to minimise disturbances. The traffic situation and VMS are looked after 24 hours a day, and regional traffic information allows events such as roadworks to be planned for and incorporated into radio stations and driver navigation systems. The VMS signs in particular are very useful and diverse, automatically calculating information such as traffic speed, traffic volume, moisture and visibility before the most appropriate message is automatically selected for the situation.[319] Speed limits can be automatically set, as well as warning notices including “Traffic Jam” and “Slippery Road” to ensure smooth traffic flows and the safety of drivers.

An overarching co-benefit of dynamic traffic management is quality of life for the residents of the city. If dynamic traffic management is employed effectively, it should reduce congestion and journey times for those travelling in and around the city; this in turn makes for happier residents. People can be much surer of their journey time (as it should be more consistent), which reduces stress from being in traffic as well as decreasing the likelihood of being late for work, appointments, or other commitments.

4.5.2 Environmentally sensitive truck routeing

HGVs are key sources of pollutants in many cities. They are particularly polluting in a number of ways: they tend to be diesel vehicles, and as of yet there are no hybrid or EV alternatives; HGVs travel long distances and therefore burn much fuel; and they are heavier than cars or LGVs, so require more power to pull away if they have been stationary. They also pollute indirectly, especially in cities, where unloading by the side of the road means other vehicles have to travel around them which can cause congestion, leading to high pollution via other vehicles. Another consideration is that this behaviour can make roads less safe for cyclists and therefore discourage switching to this mode of transport.

Environmentally sensitive truck routeing may address one, or a few of these issues. If pollution hotspots have been identified (for example by air quality measurement data) then it may be possible to ban HGVs from these routes altogether. However, this is likely to meet a lot of resistance from delivery companies and may not be practical depending on the other routes through the city. Another option could be a partial ban, ensuring HGVs can only travel the most polluted routes during times when traffic levels are low. This reduces pollution in two ways: at times of high traffic, pollution levels are likely to be high, so removing some of the most polluting vehicles at these times should reduce peak pollution levels; in addition, the removal of HGVs unloading during peak traffic times is likely to reduce congestion (as other vehicles don’t have to move around the HGVs) and again reduce pollution during those times. A key aspect to consider is that the re-routeing of HGVs from the most polluted locations does not distribute the air quality issues to other parts of the city.

In Cambridge (UK), HGVs contribute approximately 31% of NOx emissions in the city centre. Since HGVs are a significant contributor to local emissions, a priority within Cambridge’s AQAP is to reduce emissions from HGV traffic. To do this, measures are in place to reduce the need for HGVs in the centre, such as converting ‘last mile’ deliveries to use electric cars, taxis or bikes, using unified consolidation centres and Click and Collect Hubs to reduce the reliance on HGV deliveries (see Section 4.3.4). Access will also be restricted to the city centre due to the CAZ, which would require all HGVs entering the CAZ to be at least Euro VI standard. Delivery time restrictions will be put in place, meaning that HGVs are not permitted within the city centre between the hours of 10am – 4pm.[320] It is estimated that this would lead to a 90% reduction in emissions from HGVs, assuming no Euro VI HGVs currently in the fleet.[321]

[319] Traffic control with Variable Message Signs, Berlin, https://www.berlin.de/sen/uvk/en/traffic/traffic-management/traffic-control/
[320] Cambridge City Council Air Quality Action Plan 2018 – 2023, 2019, p.55-56, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf
[321] Cambridge City Council Air Quality Action Plan 2018 – 2023, 2019, p.43, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf

The city of Reutlingen in Germany outlined a 'truck route concept' in their 2018 "Master plan for the design more sustainable and emission-free mobility".[322] The concept includes three specific actions: introduction of a blue sticker for the environmental zone, establishment of freight traffic centres, truck loading zones and service points, and relocation of the freight centre. These actions would be funded by a fund for 'municipal climate protection model projects' covering up to 80% of costs and a minimum of €200,000 (approximately IND 18 million). HGV-specific bans are already implemented on certain routes in the city; however, the truck route concept will complement the bans and provide more support for HGV drivers / companies. It is estimated that at pollution hotspots, a reduction in NOx of 11% – 14% could be achieved. In the remainder of the city, 1% – 3% NOx reduction is expected.

Reduced HGV traffic in cities will also reduce traffic congestion because these vehicles tend to move more slowly than other vehicles (taking longer to accelerate and decelerate) and also cause blockages if parked somewhere for delivery, or if they break down. As HGVs are some of the most polluting vehicles, their removal has particularly strong impacts on air pollution and reduction in GHG emissions.

4.5.3 Parking controls

The main purpose of parking controls in terms of air quality is to discourage use of private vehicles in the city. However, it is important to recognise that some citizens may still have to, or choose to, travel by private vehicle and access is still required. A balance must be struck between discouraging the use of private vehicles and still enabling accessibility for them. As well as discouraging car use, it is important to make other modes of transport more attractive so that there are multiple reasons for changing to another form of transport. A number of other measures in this report help achieve this, however in terms of parking controls, converting private car parking spaces to bicycle parking spaces or (if appropriate) footpaths / cycle paths / green spaces will encourage people to travel by bicycle or on foot instead of by car.

In the UK, a Workplace Parking Levy (WPL) has been considered as a measure to discourage commuting by car in Cambridge, by reducing commuter traffic congestion and raising funds. The funds from the WPL can be re-invested into schemes which support more sustainable transport options for commuters, such as improved bus services. The WPL would be implemented for employers in the city with more than 300 employees, but the area for implementation has not yet been specified.[323] Other methods of parking controls are also supported, such as on-street parking controls, reducing city centre parking, and providing parking spaces for carshare vehicles.[324]

In Oxford, also in the UK, parking management is seen as one of the most effective measures to tackle congestion and air pollution. The Oxfordshire Parking Policy of 2014[325] included objectives to manage travel demand and reduce the need to travel by car, for instance by supporting more sustainable travel choices such as public transport, avoiding over-provision of parking spaces, and developing park and ride services. These objectives have now been expanded with new and ambitious parking policies in the Oxford Transport Strategy[326] (OTS) and Oxford Local Plan.[327] The OTS includes plans for Controlled Parking Zones (CPZs – areas where on-street parking is restricted during specified times), which are used to achieve the strategic management of traffic and aim to remove commuter and other non-residential parking from residential areas in the city.[328] The cost of a penalty ticket for parking in the

[322] Master plan for the design more sustainable and emission-free mobility, Green City Plan Reutlingen, 2018, available online at: https://www.reutlingen.de/de/Rathaus/Rathaus-Themen/Verkehr-und-Mobilitaet/Green-City
[323] Cambridge City Council Air Quality Action Plan 2018 – 2023, 2019, p.74, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf
[324] Cambridge City Council Air Quality Action Plan 2018 – 2023, 2019, p.70-74, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf
[325] Oxfordshire Parking policy, 2014, available online at: https://www.oxfordshire.gov.uk/sites/default/files/file/roads-and-transport-parking/parking-policy.pdf
[326] Connecting Oxfordshire volume 8 part i - Oxford Transport Strategy, 2015, available online at: https://www.oxfordshire.gov.uk/residents/roads-and-transport/connecting-oxfordshire/area-strategies
[327] Oxford Local Plan 2036, 2020, available online at: https://www.oxford.gov.uk/downloads/file/7380/adopted_oxford_local_plan_2036
[328] Connecting Oxfordshire volume 8 part i - Oxford Transport Strategy, 2015, p.28, available online at: https://www.oxfordshire.gov.uk/residents/roads-and-transport/connecting-oxfordshire/area-strategies

wrong place is currently between £50 – £70 (approximately IND 5,000 – IND 7,000).[329] Enforcement is targeted at main roads and bus routes, to reduce congestion.[330] A zonal parking charge system has been adopted so that becomes cheaper to use alternative transport such as buses and park & ride facilities instead of driving into the city centre to park. A WPL has also been introduced to gain control over the use of private cars used to travel to work within the city, encouraging a shift to more sustainable modes of transport. The WPL generates funds which can be reinvested into the transport network.[331] The Oxford Local Plan supports the delivery of the OTS and promotes sustainable development management policies. For example, when planning new developments, factors such as housing density and layout of routes for public transport, walking and cycling need to be considered to encourage modal shift and reduced travel. [332]

Reutlingen in Germany sets out a number of parking controls in their "Master plan for the design more sustainable and emission-free mobility".[333] Parking fees will be expanded to those areas where there is currently no charge, and current fees will be adjusted – this may include price increases as well as variable charges for different vehicle types or different times of day. Some parking areas will be dismantled and converted into bicycle parking spaces, and all sidewalk parking will be removed. These actions do not have funding assigned to them, however, are expected to work alongside the parking guidance measures outlined in Section 4.5.4.

Zurich, Switzerland, has a comprehensive parking management policy.[334] Public parking supply has been shortened continuously from the 1990s. There was a temporary increase in the number of parking spaces in 2013, as an urban public space reorganisation necessitated a new car park. However, the numbers were expected to fall again during 2015 with continued parking management. Parking fees are deliberately high and constantly adapted; a further increase in parking fees for both public and residential parking spaces is planned to promote car-free living, although a reported 48% of households are already car-free. Parking in designated 'blue zones' requires a permit which can be obtained online.[335] Fines of CHF 40 (approximately IND 3,200) or greater can be expected for those who do not adhere to the strict parking rules in Zurich.[336]

A key benefit of parking controls is that although raising charges will hopefully have the intended effect of reducing private vehicle use, the income from parking charges should still exceed the cost to implement the measures. Another co-benefit of parking controls is the improvement of the environment for walking and cycling; if sidewalk parking spaces are removed and some car parking spaces are converted to, for example, bicycle parking spaces or green spaces, the environment will be more pleasant and feel safer for those who travel by bike or on foot. Travelling via these methods of transport has health benefits as well. Finally, removal of on-street parking generally leads to a reduction in congestion, further reducing air pollution as traffic flows are smoother (see Section 4.5.5).

4.5.4 Parking guidance system

Traffic looking for a parking space makes up a significant proportion, especially in city centres, of total traffic volume. In addition, cars searching for a parking space are likely to be moving slowly and stop-starting, which emits more emissions than driving smoothly at a constant, intermediate speed. An optimised parking guidance system, and especially a digitised system, could take into account real-time data such as traffic and parking space occupancy. This would reduce the time taken to find a parking space and therefore reduce associated pollutant emissions. In some cases, if the parking guidance

[329] Parking tickets and appeals, Cambridge, https://www.cambridgeshire.gov.uk/residents/travel-roads-and-parking/parking-permits-and-fines/parking-tickets-and-appeals
[330] Oxfordshire Parking policy, 2014, p.7, available online at: https://www.oxfordshire.gov.uk/sites/default/files/file/roads-and-transport-parking/parking-policy.pdf
[331] Connecting Oxfordshire volume 8 part i - Oxford Transport Strategy, 2015, available online at: https://www.oxfordshire.gov.uk/residents/roads-and-transport/connecting-oxfordshire/area-strategies
[332] Oxford Local Plan 2036, 2020, p.21, available online at: https://www.oxford.gov.uk/downloads/file/7380/adopted_oxford_local_plan_2036
[333] Master plan for the design more sustainable and emission-free mobility, Green City Plan Reutlingen, 2018, available online at: https://www.reutlingen.de/de/Rathaus/Rathaus-Themen/Verkehr-und-Mobilitaet/Green-City
[334] European City Ranking 2015, Best practices for clean air in urban transport, 2015, http://www.sootfreecities.eu/sootfreecities.eu/public/
[335] Parking cards & permits, Zurich, https://www.stadt-zuerich.ch/content/pd/de/index/dav/parkkarten_bewilligungen.html
[336] Possible parking in Zurich, https://www.zuerich.com/en/visit/getting-around-in-zurich/parking-zurich

system was able to be checked before a journey began, some drivers may be encouraged to avoid trying to find a space in a busy car park and use another mode of transport instead.

There are different types of parking guidance systems that could be implemented depending on the needs of the city. A relatively simple option, employed in many cities, is to have automatically updating signs on the routes into the city showing the number of available parking spaces at each site. Another option is via an app, which would allow drivers to check the status of car parks before setting off on their journey. The app may also be able to suggest a route to get to the chosen car park.

The city of Reutlingen in Germany has had a parking guidance system (PLS) in place since 2005, however, wishes to update it to be in line with the latest technology. [337] The city envisages an app that links to real-time data for parking and traffic (collected via sensors), and estimated a cost of €500,000 (approximately IND 44 million) to fully digitise the system. Although the initial investment costs are high, the maintenance of such a system is relatively low-cost and once implemented, the reduction in emissions should be quite immediate depending on the uptake.

Mannheim, also in Germany, provides online information about the location of its 20+ car parks as well as the up-to-date availability of the 10,000 parking spaces.[338] The parking website lists the number of available spaces in each car park, along with the exact location of the car park and the prices for every available duration.[339] The site is updated every few minutes, so the information is very accurate. In addition, the site warns of any closures, such as due to flood risk. The “Parking in Mannheim” app is also available, with the same features as the website.

The Deutsche Telekom app "Park and Joy" is available in the city of Hamburg, Germany, to enable users quickly and easily find a parking space.[340] The app receives information from sensors on Hamburg’s parking lots, placed by local transport company LBV. The sensors indicate whether a parking space is vacant (or not) by communicating through a narrowband Internet of Things (NB-IoT) solution. Other sources of data are also used to calculate the probability of a parking space becoming vacant, for example information from parking ticket machines, parking operators or mobile phones.[341] After parking, the ticket is paid for via the mobile application, simplifying the whole process from start to finish. The first hundred sensors were installed in the Wandsbek Markt area of the city, with up to 11,000 sensors expected across Hamburg by the end of 2019. With this project, the State Office for Transport strives to improve traffic control and the management of available parking space through the means of real-time information in parking space utilization.[342]

For users of a parking guidance system, co-benefits include time saved by not looking for a parking space, and increased comfort / reduction in stress from searching or being stuck in traffic. A reduction in traffic related to searching for a parking space will also lead to a reduction in GHG emissions (and therefore climate change benefits), less congestion, and potentially fewer road accidents.

4.5.5 Traffic flow smoothing

A smooth driving style, with a reduction in sharp increases or decreases in speed (acceleration and braking) is the most efficient way to drive and therefore limits air pollution. In particular, sharp braking increases the friction between brake pads, as well as between tyres and the road, so PM emissions are increased. In cities, congestion is regular, if not the norm, and in this situation there is no smooth driving (as well as lots of idling). Measures to smooth flows of traffic in cities will make the driving experience more pleasant, reduce congestion, and reduce air pollution from vehicles.

The possible mechanisms for implementation of this measure link very closely to those discussed in Section 4.5.1, dynamic traffic management. Some of the options described by Transport for London (TfL) are:

[337] Master plan for the design more sustainable and emission-free mobility, Green City Plan Reutlingen, 2018, available online at: https://www.reutlingen.de/de/Rathaus/Rathaus-Themen/Verkehr-und-Mobilitaet/Green-City
[338] Parking in the city centre, Mannheim, https://www.visit-mannheim.de/en/directions
[339] Currently free parking spaces, Mannheim, https://www.parken-mannheim.de/
[340] Hamburg Park and Joy, smart parking for a digital city, https://smartcityhub.com/mobility/hamburg-smart-parking-digital-city/
[341] Intelligent Parking in Hamburg, https://www.eltis.org/discover/news/intelligent-parking-hamburg
[342] ITS projects in Hamburg, https://www.hamburg.com/business/its/11747506/projects/

- SCOOT (Split Cycle Offset Optimisation Technique) – The careful management of traffic signals to give more time to vehicles queuing from a certain direction.
- SASS (System Activated Strategy Selection) – In a similar way to SCOOT, this changes traffic signal timings according to a particular traffic problem.
- Signal timing reviews – The reallocation of traffic signal time from pedestrians to motor traffic, amending the amount of time that traffic spends at a pedestrian crossing.
- Pedestrian countdown – Again, more allocation of signal time phases to motor vehicles, with a countdown of the amount of time pedestrians have left to cross the road.
- Signals removal – The stripping out of traffic signals that are deemed unnecessary, or unjustified, for pedestrians, or 'traffic'.

Traffic smoothing also needs to consider effective road space management (including road layout, cycle lanes and bus lanes), on-street parking, delivery / loading arrangements, signage, and road works. Each city is different, so any one measure will not necessarily work for every city.

The Comprehensive Air Quality Action Plan for Kolkata, India, includes proposed measures to remove congestion from densely populated/most frequented road stretches through traffic re-engineering.[343] This measure includes the development of an integrated automated network system of traffic light signals, whereby traffic light systems are automated and upgraded, reducing congestion, and improving traffic flow. Traffic signals may also be replaced with circular roundabouts to aid the removal of congestion from densely populated/most frequented road stretches Another related action under the measure is the introduction of Supervisory Control And Data Acquisition (SCADA) software to provide better monitoring and control of traffic management, which aims to provide drivers with a faster, safer trip on roads. Smart Variable Message Signs can also be introduced. These are digital road signs which are used by Kolkata police to inform car drivers about specific temporary events and real-time traffic conditions. This can be further developed by introducing an early alarm system during traffic congestion for the benefit of commuters on major routes, to facilitate route diversion and synchronise traffic movements. In areas with high levels of pedestrian road usage, underpasses can be constructed to minimise the vehicle and passenger paths from crossing which slows traffic. In order to understand the most effective traffic signals to install, Kolkata is conducting an audit and review of traffic signalling systems at all intersections, particularly traffic hotspots, in the Kolkata Municipal Corporation (KMC) area.[344]

Berlin, the capital city of Germany, has one of the largest state-of-the-art traffic control centres (Verkehrsregelungszentrale, VKRZ) in Europe (see Section 4.5.1).[345] The VKRZ has a key role in deciding on permanent traffic regulations in the city, including: the necessity and installation of traffic lights, route signage, parking guidance systems, creation of bus lanes and stops in accordance with the transport provider (BVG), road traffic measures for diplomatic missions and federal authorities (including security measures), the marking of regional cycling routes, speed limits, one-way streets, right-of-way regulations and ban on turns, as well as pedestrian crossings.[346] The road traffic authorities operate with the police, road construction and maintenance departments, the transport provider BVG, environmental authorities, the respective interest groups, depending on the matter at hand, in order to keep the flows of traffic in Berlin as smooth as possible.

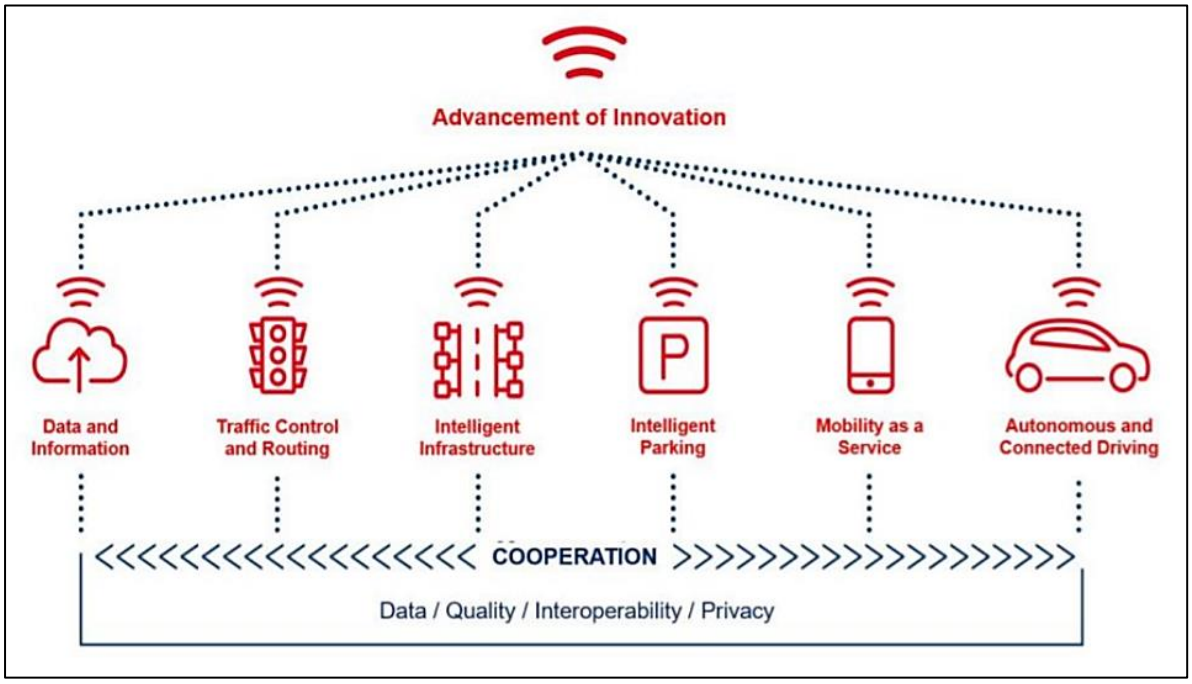
In Hamburg, Germany, one of the ITS pilot projects is the 'Traffic Light Forecast' for which a conference paper was published in November 2020. The State Office for Streets, Bridges and Waters (LSBG) and cooperating partners Swarco Traffic Systems, HERE and Audi, have completed a successful test run of high-quality traffic light forecast services[347]. The project aims to promote the development of innovative applications such as TTG (Time-To-Green) and GLOSA (Green Light Optimized Speed

[343] Comprehensive Air Quality Action Plan for Kolkata, 2018, p. 11, available online at: https://cpcb.nic.in/Actionplan/West%20Bengal.pdf
[344] Comprehensive Air Quality Action Plan for Kolkata, 2018, p. 11-16, available online at: https://cpcb.nic.in/Actionplan/West%20Bengal.pdf
[345] Traffic Control Centre (VKRZ), Berlin, https://www.berlin.de/sen/uvk/en/traffic/traffic-management/traffic-control-centre/
[346] Permanent regulations, Berlin, https://www.berlin.de/sen/uvk/en/traffic/traffic-management/permanent-regulations/
[347] ITS projects in Hamburg, https://www.hamburg.com/business/its/11747506/projects/

Advisory) for motorised and non-motorised traffic.[348] These services can contribute to optimisation of traffic, leading to a reduction of pollutants. More than 1,000 traffic lights throughout the city are to be equipped with these light forecasts. The six areas of action for the Traffic Light Forecast system are shown in Figure 13, which include data and information, intelligent infrastructure, and intelligent parking.

Smoother traffic flows are reported to be safer for cyclists – it is at junctions, traffic lights and other stopping situations where cyclists are put in more danger from motorised vehicles (as well as being exposed to more air pollution during those times. Another key co-benefit is the quality of life gained by reduction in congestion; journeys become less stressful, journeys are more consistent (leading to fewer worries about being late to work/meetings/events etc.), and fewer accidents occur due to reduction in stop-start traffic.

Figure 13: Six areas of action for the Traffic Light Forecast system in Hamburg, Germany, as laid out in Figure 1 of the conference paper 'Traffic Light Forecast in Hamburg' (2020)[349]



4.5.6 Speed limits

As detailed in the previous measure (Section 4.5.5), a smooth driving style with minimal braking and accelerating is the least-polluting way of driving. In particular, sharp braking increases PM emissions due to the friction between brake pads, as well as between tyres and the road. On major roads such as motorways, a high speed limit is appropriate, however, in cities a high speed limit will lead to sharp braking and aggressive acceleration, thus increasing pollution. There is an important balance in the speed limits set, as driving at a very low speed can also cause increased pollution. As with traffic smoothing measures, the methods used to calm the traffic are important and their impact on the behaviour of drivers must be considered.

Cities are able to set the speed limits on their roads, however, the exact speed limit for each road type must be decided, as well as if any additional measures are required for enforcement of the speed limit. On major roads, such as ring roads, it may be appropriate to reduce the speed limit by a greater amount (e.g. 20 – 30 km/h) than on smaller, inner-city roads (where a 5 – 10 km/h reduction would be more appropriate). With regards to enforcement, certain traffic calming measures like speed bumps may not be the most effective because they encourage the driver to slow down sharply as they approach the speed bump, and then accelerate away from it. Speed cameras are an option to catch those breaking

[348] Traffic Light Forecast in Hamburg, Paper number ITS-TP2278, Virtual ITS European Congress, 9-10 November 2020, https://www.researchgate.net/publication/347511050_Traffic_Light_Forecast_in_Hamburg/download

[349] Traffic Light Forecast in Hamburg, 2020, Figure 1, p.2, available online at: https://www.researchgate.net/publication/347511050_Traffic_Light_Forecast_in_Hamburg

the speed limit, however, at lower speeds these may not be appropriate, and may present similar pitfalls as speed bumps in that drivers slow down as they pass the camera, but speed up after passing it. There is also the consideration that just the reduction in the speed limit (with no enforcement) will decrease speed on the road, even if not as low as the set limit.

The city of Zurich in Switzerland currently limits traffic to 30 km/h in most residential areas.[350] Main roads are generally limited to 50 km/h. In the context of a street noise reduction programme, the speed limit of an additional 100 municipal streets (or sections of streets) has been reduced to 30 km/h, as well as the limits on a number of supra-municipal streets. The city also wants to continuously introduce shared spaces, with 20 km/h speed limit zones and pedestrian priority.

Speed restrictions on certain roads are stated to be one of the main measures to alleviate the negative effects of car travel in Berlin, Germany, by the Berlin Senate Administration.[351] The city implemented a speed limit of 30 km/h at night mainly to reduce noise pollution, but also acknowledges that this measure will have a positive impact on air pollution as well. The 'Speed-30' or 'Tempo-30' concept is an efficient measure because it is able to be implemented by the transport authorities on a road in a timely manner. 'Tempo 30' was ordered and implemented at night (10 p.m. to 6 a.m.) on street sections that were heavily used at night – now covering 164 km of main roads in Berlin. Prior to its implementation, a study was completed along the most heavily used roads to determine where a maximum number of residents could be affected, without affecting the metro lines and the main streams of nightly traffic to too great an extent.[352]

Stockholm, Sweden, hosted ministers, and experts from more than 130 countries at the 3rd Global Ministerial Conference on Road Safety during February 2020. The event was in collaboration with the WHO and aside from discussing road safety, aimed to link road safety to other sustainability challenges reflected in the 2030 Agenda for Sustainable Development.[353] The outcome of the conference was the 'Stockholm Declaration' – 18 resolutions linking road safety to sustainable development. Resolution 11 describes the universal use of 30 km/h speed limits in areas where vulnerable road users and vehicles mix; it also notes that efforts to reduce speed in general will have a beneficial impact on air quality and climate change as well as being vital to reduce road traffic deaths and injuries. Enforcement was also discussed – in order for the 30 km/h speed limits to be effective, physical enforcement (e.g. speed bumps, road narrowing) must be used in addition to law enforcement.

The greatest co-benefit of implementation of speed limits is the increase in safety. Accidents are less likely to occur at slower speeds because the driver has more time to change direction or apply the brakes than at a higher speed. In addition, accidents that do occur at lower speeds cause less serious injuries and fewer fatalities than those at higher speeds. Travelling at a continuously slower speed, with less stopping and starting, may also reduce noise pollution.

[350] Soot Free cities – Zurich, http://www.sootfreecities.eu/sootfreecities.eu/public/city/zurich
[351] Speed limits, Berlin, https://www.berlin.de/sen/uvk/en/traffic/transport-policy/speed-limits/
[352] Evaluierung von Tempo 30 an Hauptverkehrsstraßen in Berlin, 2013, available online at: https://www.berlin.de/sen/uvk/_assets/verkehr/verkehrspolitik/tempobeschraenkungen/ergebnisse_evaluierung_tempo30.pdf
[353] Stockholm Declaration links road safety to sustainable development, https://www.eta.co.uk/2020/02/28/stockholm-declaration-links-road-safety-to-sustainable-development/

4.5.7 Evaluation of transport and urban planning measures

The transport and urban planning measures described above have been evaluated according to the criteria outlined in Section 4. Table 6 provides a summary of the results.

Table 6: Evaluation of transport and urban planning measures

Measure	Evaluation according to criteria						
	Which pollutants are impacted?	Air quality impact (1-5)	Costs (1-5)	Co-benefits (1-5)	Reliance on other measures (1-5)	Innovation (1-5)	Prospective timescale (1-5)
Dynamic traffic management	**NOx, PM, SO_2**	✓✓✓	✓✓	✓✓✓✓	✓✓✓✓	✓✓✓✓✓	✓✓✓✓
Environmentally sensitive truck routeing	**NOx, PM, SO_2**	✓✓✓	✓✓✓✓	✓✓✓✓	✓✓✓✓	✓✓	✓✓
Parking controls	**NOx, PM**	✓✓✓✓	✓✓✓	✓✓✓	✓✓✓✓	✓✓	✓✓
Parking guidance system	**NOx, PM**	✓✓	✓	✓✓✓✓✓	✓✓✓✓	✓✓✓✓	✓✓✓
Traffic flow smoothing	**NOx, PM, SO_2**	✓✓	✓✓✓✓	✓✓✓✓	✓✓	✓✓✓✓✓	✓✓✓✓
Speed limits	**NOx, PM, SO_2**	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓

4.6 Air quality monitoring and data

4.6.1 Collection of air quality data - increase in number and quality of stations

Collection of air quality data is important for a number of uses, including: checking if statutory air quality standards and targets are met, and reporting on this, informing the public about air quality, identifying long-term trends in air pollution concentrations, and assessing the effectiveness of air quality policies to control air pollution.

EU Directive 2008/50/EC sets out requirements for air quality monitoring in EU countries.[354] Countries are split up into air quality zones or agglomerations for the purposes of air quality reporting. The air quality monitoring requirements for each zone/glomeration then includes the minimum number of sampling points (which is dependent on the population of a zone or agglomeration and the pollutant of consideration; Annex V), the location of monitoring stations (dependent on where the population is present, where concentrations are highest, requirements on distances from roads and buildings, and locations of industrial sources; Annex III), the pollutants that must be measured (at least a certain number of locations in the country, or a defined spatial area), data quality requirements (data capture, uncertainty, etc.; Annex I), and certain reference methods for measuring different types of pollutants (Annex VI). Annex VII of the Directive sets out the thresholds for alerts to be sent out to the public, if concentrations of SO_2, NO_2 and/or O_3 breach a certain value. The Directive also sets out requirements to inform the population about ambient air quality in the country/city, "*free of charge by means of any easily accessible media including the Internet or any other appropriate means of telecommunication*"; this is set out in full in Annex XVI. There are separate requirements for O_3 monitoring than for other pollutants, and there may also be national requirements for air quality monitoring that countries have set themselves.

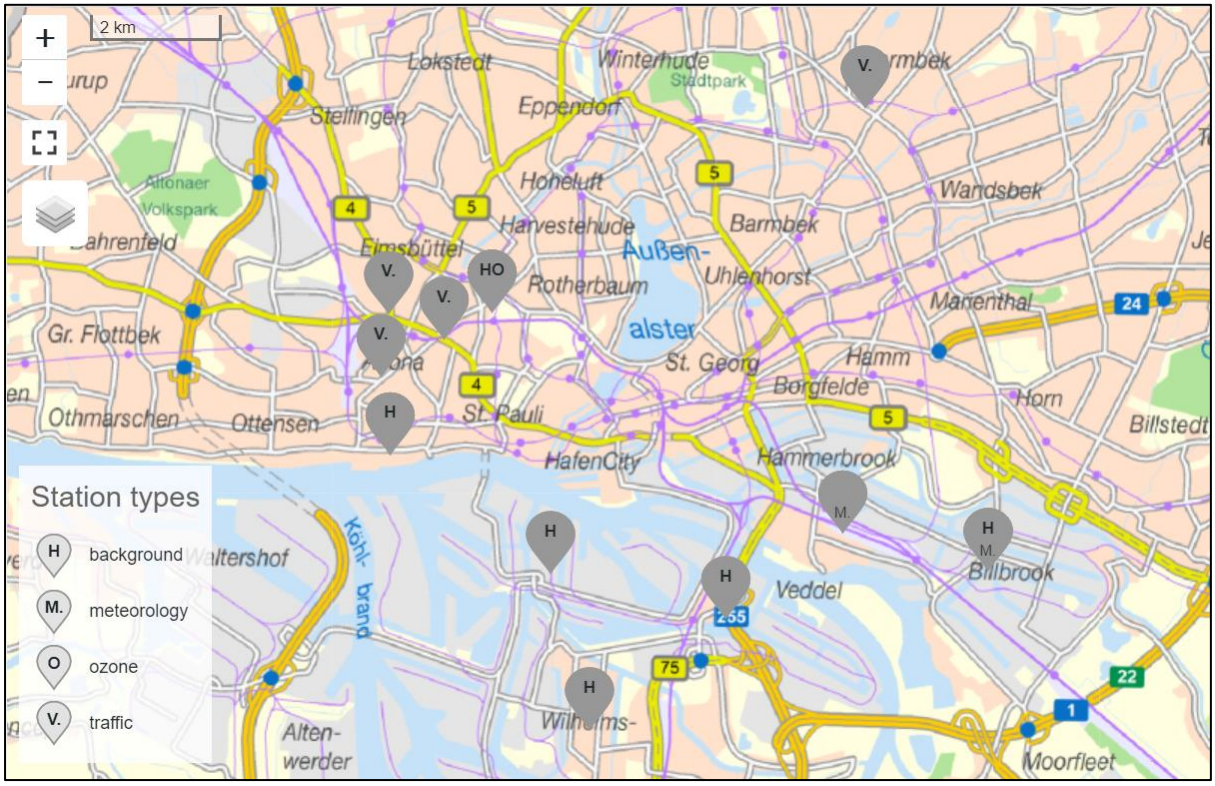
Air quality monitoring is considered in the Comprehensive Air Quality Action Plan for Kolkata,[355] India, as a way to update and improve protocols for air quality management. Research studies such as air pollution inventories, source apportionment, health impact studies and exposure impact studies can use air quality data to help to guide policy. The West Bengal Pollution Control Board (WBPCB) has already made all semi-automatic air monitoring stations functional with effect from 2016, providing air quality monitoring information for Kolkata daily.[356] An additional five Continuous Ambient Air Quality Monitoring Stations (CAAQMS) are being set up in order to cover the entire of Kolkata city, with two run by WBPCB already in place. Source inventory and source apportionment studies are commissioned to the National Environmental Engineering Research Institute (NEERI) in Nagpur, which is engaged in conducting the source apportionment study in Kolkata and Howrah. The government may also initiate research projects or scientific studies, collaborating with academic or research institutions, and using expertise to develop protocols for air quality management.[357]

Hamburg in Germany has an air investigations department which lies within the Institute for Hygiene and the Environment.[358] The air investigations department is responsible for examining and assessing air quality in Hamburg, including operating the automatic Hamburg air measurement network (HaLm),[359] carrying out other air measurements programs, naming new private measuring institutes after a corresponding competence test and monitoring their quality, and generally being experts in questions of air quality, measurement strategy and measurement technology for the Hamburg administration as well as in the framework of federal / state working groups and standardization committees. The air quality monitoring website provides a map showing the most recent air quality monitoring (by air quality index value rather than concentrations) in the city across all monitoring stations, shown in Figure 14. HaLm has been collecting data since 1984 and currently operates 18 measuring stations (comprising

[354] DIRECTIVE 2008/50/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 May 2008 on ambient air quality and cleaner air for Europe, Official Journal of the European Union, available online at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0050
[355] Comprehensive Air Quality Action Plan for Kolkata, 2018, pp.24-25, available online at: https://cpcb.nic.in/Actionplan/West%20Bengal.pdf
[356] Kolkata Air Quality Index (AQI), Real-Time Air Pollution Level, https://www.aqi.in/dashboard/india/west-bengal/kolkata
[357] Comprehensive Air Quality Action Plan for Kolkata, 2018, pp.24-25, available online at: https://cpcb.nic.in/Actionplan/West%20Bengal.pdf
[358] Environmental studies, The air investigations department, Hamburg https://www.hamburg.de/hu/luftuntersuchungen/
[359] Hamburg air monitoring network, https://luft.hamburg.de/

of background, traffic, and ozone stations), as well as a measuring vehicle, to monitor air quality.[360] The network is computer-controlled; the concentrations of all pollutant components are continuously measured and condensed into 10-minute values, which are transmitted hourly to the central computer of the air measuring network in the Institute for Hygiene and Environment. Following automatic and manual quality checks, they are kept in a database and can be evaluated with various software tools. Current hourly mean values are made available to the public via the Internet, text and announcements. Outside of the regular polling cycles, the stations report automatically to the control centre if the pre-set values are exceeded. The network is flexible - in order to record as many road sections as possible, some traffic measuring stations are converted every couple of years and other stations are operated for longer in order to follow the long-term trends. The HaLm website also has numerous articles explaining: why it is important to measure air quality in Hamburg, reports on the data for the previous months, and entire year once it has been reviewed and finalised, explanations of what the air quality index values mean, and any other research that has been conducted.

Figure 14: An example map providing an overview of active stations in the Hamburg air measurement network (HaLm), central Hamburg[361]



The Automatic Urban and Rural Network (AURN) is the UK's largest automatic monitoring network and is the main network used for compliance reporting against the Ambient Air Quality Directives (under the European Commission).[362] The automatic monitoring sites, as pictured in Figure 15, provide high resolution hourly information on measured concentrations of NOx, SO_2, O_3, PM_{10} and $PM_{2.5}$, which is communicated rapidly to the public, using a wide range of electronic, media and web platforms. Other important parameters such as ambient temperature, barometric pressure, wind direction and wind speed are also measured. The network commenced monitoring in 1973 and 150 sites currently provide information. Ricardo Energy & Environment undertakes the role of Quality Assurance and Control Unit (QA/QC Unit) for the entire AURN. The responsibility for operating individual monitoring sites is

[360] Environmental studies, Hamburg air monitoring network, https://www.hamburg.de/hu/umweltuntersuchungen/112556/hamburger-luftmessnetz/
[361] Overview of active stations, Hamburg air monitoring network, https://luft.hamburg.de/clp/messstationen-aktuelle-messdaten/clp1/
[362] Automatic Urban and Rural Network (AURN), https://uk-air.defra.gov.uk/networks/network-info?view=aurn

assigned to local organisations, such as local authority Environmental Health Officers with relevant experience in the field.

Collection of air quality data has no direct impact on emissions from transport, however, it can indirectly decrease emissions when applied alongside other measures and used to help prioritise other air quality measures. If the general public are well-informed about air quality in their area, they are more likely to take actions to improve air quality, and therefore are more likely to see health benefits.

Figure 15: Automatic Urban and Rural Network (AURN) example of an automatic air quality monitoring station[363]

4.6.2 Collection of mobility / transport data

Collection of up to date mobility and/or transport data is valuable in being able to assess a city's current travel situation. Determination of the split between journeys made by private vehicle, public transport, cycle or on foot can help the city to work out where improvements can be made.

There are a variety of methods for collection of mobility / traffic data. The most simplistic is a survey, which could be conducted online, or by traffic counters in certain areas of interest in the city. However, surveys are likely to be inaccurate; you cannot guarantee who will answer an online survey and how truthfully, and traffic counts by humans are likely to encounter human error. Automatic traffic counting is another, more reliable method, but the initial costs will be greater than for a survey. There are also issues, depending on the method of automatic counting, with data protection.

In order to support traffic management and congestion relief in Cambridge (UK), a large Automatic Number Plate Recognition (ANPR) camera-based traffic survey has been conducted in the city. The study will support a new traffic model to better understand potential options for traffic management and network changes. The dataset provides 'Origin and Destination' reports from June 2017. Data from the ANPR survey is to be used to determine a 2017 baseline, then potential options with and without a range of restrictions can be considered.[364] The overarching aim of the survey is to provide a firm evidence base for future decisions, by improving understanding of how the traffic network is being used and the impacts of vehicle use.[365]

[363] Automatic Urban and Rural Network (AURN), available online at: https://uk-air.defra.gov.uk/networks/network-info?view=aurn
[364] Cambridge City Council Air Quality Action Plan 2018 – 2023, 2019, p.44, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf
[365] Greater Cambridge ANPR Data: Origin to Destination Reports, 2020, available online at: https://data.gov.uk/dataset/e5b97c17-9dc9-45fb-a5de-d8d85509c4fa/greater-cambridge-anpr-data-origin-to-destination-reports

The city of Hamburg in Germany, as part of their "Master Plan for Designing More Sustainable and Emission-Free Mobility in Hamburg"[366], describes the 'aVME-HH' project where infrared / thermal imaging cameras are installed on traffic lights and used to record traffic data including traffic types, traffic volume, and even vehicle occupancy. Hamburg is to host the ITS World Congress in October 2021,[367] and includes this project, led by Hamburg Verkehrsanlagen GmbH, in its list of ongoing ITS projects in the city.[368] The data from the cameras will be used by the administration to enable traffic control and future planning. Thermal imaging cameras are well-established and so although they are not innovative, the method is tried and tested and therefore likely to be applicable to Cuttack and Bhubaneswar. The project is stated to have high initial implementation costs, but low operational and maintenance costs.

Hamburg is also set to launch a platform for comprehensive digital documentation, analysis, and planning of new mobility services in urban areas. The platform is being developed and operated in cooperation with Hamburg-based start-up Wunder Mobility,[369] to help the city understand how to best use new mobility services such as e-scooters, taxis, and rental bicycles. The platform aims to gain a deeper understanding of the interaction between new mobility offerings and the existing transport infrastructure, and to use the findings to develop solutions for greener and more efficient mobility in the city. The project is preceded by documentation and analysis of the use of electric scooters. From July 2019, four suppliers have been offering up to 800 rental scooters across the city of Hamburg.

Essen, in Germany, aims to achieve shares of public transport, private vehicles, bicycle and on foot at 25% each by 2035 – referred to as the 'Four x 25' target.[370] A transport survey from 2011 placed the shares at approximately 54% private vehicle, 21% on foot, 20% via public transport and just 5% cycling. Compared to previous surveys from 1989 and 2001, private vehicle use hardly changed, but public transport and bicycle traffic increased, and the proportion of pedestrians fell continuously.

The city of Mannheim in Germany has gone further than just determining shares of transport options, by splitting them across the distance travelled for that journey. The System of Representative Transport (SrV) transport survey "Mobility in Cities" found that for journeys of 1 km or less, around 70% of journeys were made on foot and just 13% by private car. For journeys of 1 to 3 km, approximately one third of journeys were made by private car, 27% by foot and another 27% by bicycle.[371] For journeys between 3 and 5 km, over half of journeys were made by private car (54%), increasing to 65% of journeys between 5 and 10 km and over three quarters of journeys over 10 km. The share of public transport journeys increased with distance, however, did not exceed 22%. One third of the population of Mannheim lives within 5 km of the city centre, suggesting that the journeys of up to 5 km are the most prevalent; increasing the proportion of these journeys utilising public transport is therefore a key target for Mannheim.

It should be noted that collection of transport and/or mobility data has no direct impact on emissions from transport. However, it can indirectly decrease emissions when applied alongside other measures and used to help prioritise other air quality measures. Air quality and mobility data can be used to measure the impact of measures to address pollutant emissions from transport, over a period of time. In addition, it is also likely to improve the quality of life in a city, by informing the administration as to what the current traffic-related issues are (such as congestion periods) so they can be addressed.

[366] Master Plan for Designing More Sustainable and Emission-Free Mobility in Hamburg, as part of the Immediate Program for Clean Air 2017 – 2020, 2018, available online at: https://www.bmvi.de/SharedDocs/DE/Anlage/K/Masterplaene-Green-City/hamburg.pdf?__blob=publicationFile
[367] ITS World Congress 2021, https://itsworldcongress.com/?cookie-state-change=1612172941002
[368] ITS Projects in Hamburg, https://www.hamburg.com/business/its/11747506/projects/
[369] Wunder Mobility, https://www.wundermobility.com/
[370] Master Plan traffic, Essen, 2018, available online at: https://www.bmvi.de/SharedDocs/DE/Anlage/K/Masterplaene-Green-City/essen.pdf?__blob=publicationFile
[371] Master plan "Sustainable Mobility for the City", Green City Plan, Immediate program for clean air 2017 – 2020, Heidelberg, Ludwigshafen and Mannheim, 2018, available online at: https://www.bmvi.de/SharedDocs/DE/Anlage/K/Masterplaene-Green-City/heidelberg-ludwigshafen-mannheim.pdf?__blob=publicationFile

4.6.3 Air quality forecasting

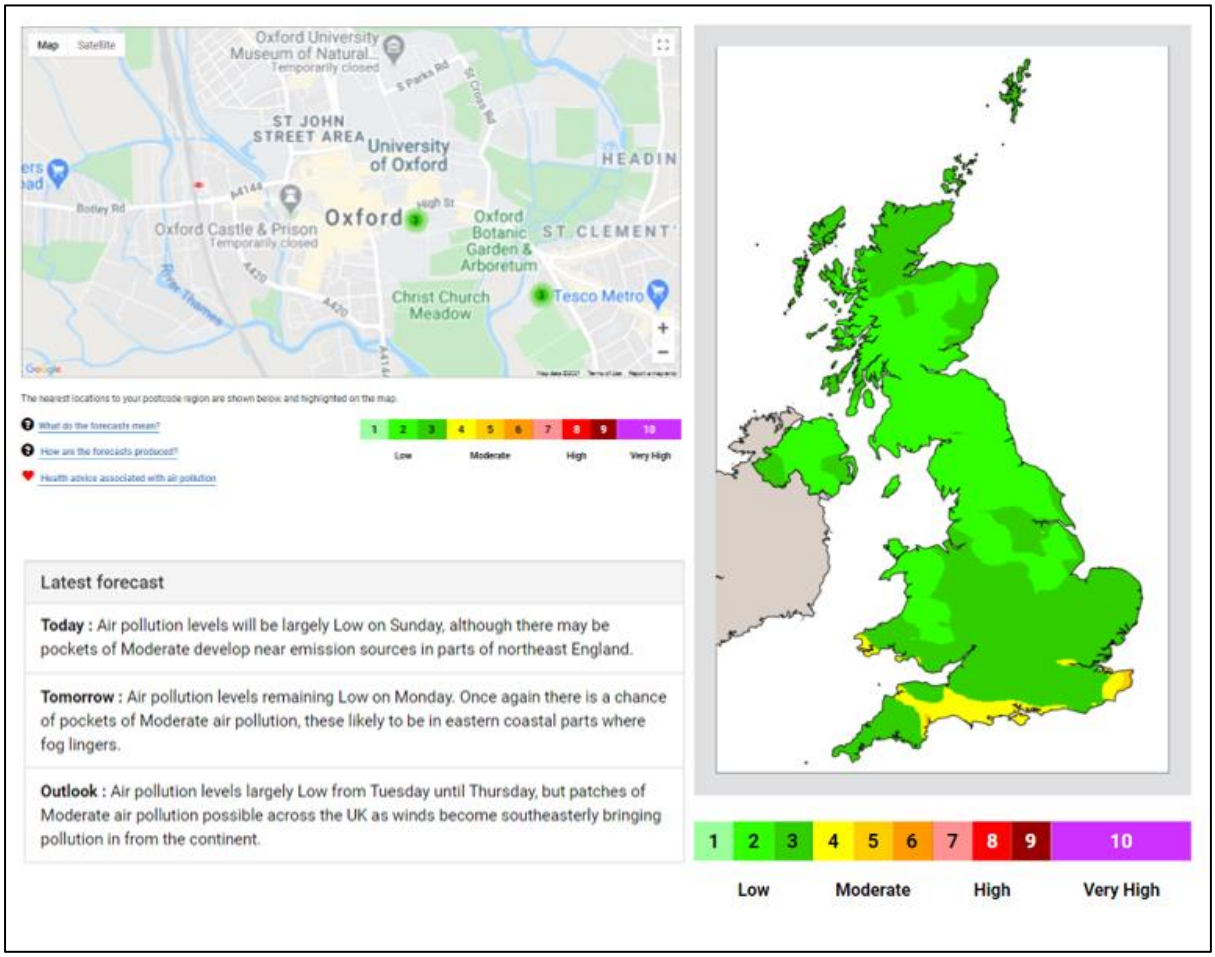
Air quality forecasting, or air pollution forecasting, uses a combination of pollutant concentration measurements, weather measurements and forecasting, chemical transport models and atmospheric dispersion modelling to predict pollutant concentrations or the air quality index for a specific location, at a certain time. Local emission sources, such as road traffic and industry, as well as long-range pollutants (e.g. Saharan dust which may be found in European cities). Pollution forecasts are often presented to the general public using maps with a colour scale that indicates the level of pollution – the scale could be pollutant concentrations, or the air quality index (taking into account multiple pollutants).

The state of Baden-Württemberg, in which Mannheim and Reutlingen are both located, provides some air quality forecasting information on the State Institute for the Environment Baden-Württemberg website.[372] There is a separate forecast for O_3 only; this forecast is published for the following day in the state and provides information on O_3 concentration trends and any expected exceedances of the threshold values. This forecast is only provided in the summer half of the year, when O_3 concentrations are higher, commencing from April/May.[373] Another forecast is provided for the pollutants PM_{10}, $PM_{2.5}$, NO_2 and O_3 using the Atmo-BW model.[374] Forecasts for the current day, previous day, and two days into the future, are presented for the aforementioned pollutants via state maps that are colour coordinated according to the pollutant level. In order to make this easy for the public to understand, the colour scale does not display pollutant concentrations, but a scale ranging from 'very good' to 'good', 'satisfactory', 'sufficient', 'bad' and 'very bad' as per the index classes of the daily air quality index (LuQx). The forecast maps are updated daily between 8am – 9am.

The UK Department for Environment, Food and Rural Affairs (DEFRA) provides an air quality forecasting website 'UK AIR', an example map shown in Figure 16.[375] The air quality forecasts are produced by the Met Office for the current day, and up to the next four days. According to the website, the Met Office model uses annual average pollutant emissions maps of the UK and Europe to simulate release of chemical species into the atmosphere.[376] The chemical reactions of these species are modelled, followed by transport and dispersion of the species across the continent. The forecast is also improved by incorporating measurements from the AURN (see Section 4.6.1). Concentrations calculated using the model and incorporated measurements allow calculation of the Daily Air Quality Index (DAQI). The UK AIR website provides maps of the DAQI across the entirety of the UK (for the current day and four days into the future) along with concise text summaries of the expected pollution today, the next day, and the outlook. Users can enter their UK postcode to find the local air pollution forecast, again in terms of DAQI. The website also has links to health advice, information about the DAQI, the latest air quality measurements by the AURN, air pollution alerts, and the UK AIR Twitter page.

[372] Forecasts, State Institute for the Environment Baden-Württemberg, https://www.lubw.baden-wuerttemberg.de/luft/prognose
[373] Ozone forecast, State Institute for the Environment Baden-Württemberg, https://www.lubw.baden-wuerttemberg.de/luft/ozon
[374] Atmo-BW, State Institute for the Environment Baden-Württemberg, https://www.lubw.baden-wuerttemberg.de/luft/atmobw
[375] UK AIR Air Information Resource, https://uk-air.defra.gov.uk/
[376] How are the forecasts produced?, UK AIR, https://uk-air.defra.gov.uk/forecasting/how-forecasts-are-produced

Figure 16: Example air quality forecast map in Oxford (left) and over the UK (right), produced by the Met Office and presented by DEFRA[377]



A co-benefit of carrying out pollution forecasting and presenting the information to the general public is that they are able to plan for predicted high concentration events. This is particularly useful for those with respiratory conditions such as asthma, who can plan when to do an outdoor activity based on the forecast pollution levels and make it safer for themselves. Providing easy-to-interpret pollution forecasting maps also enables the general population to get interested in air quality, and makes the information more accessible to children too. Increasing interest in air pollution and air quality issues helps with motivation towards other air quality measures that a government may wish to put in place.

[377] Pollution Forecast (2021), available online at: https://uk-air.defra.gov.uk/forecasting/

4.6.4 Evaluation of air quality monitoring and data measures

The air quality monitoring and data described above have been evaluated according to the criteria outlined in Section 4. Table 7 provides a summary of the results.

Table 7: Evaluation of air quality monitoring and data measures

Measure	Evaluation according to criteria						
	Which pollutants are impacted?	Air quality impact (1-5)	Costs (1-5)	Co-benefits (1-5)	Reliance on other measures (1-5)	Innovation (1-5)	Prospective timescale (1-5)
Collection of air quality data	**NOx, PM, SO_2**	✓	✓✓✓✓	✓✓	✓✓	✓✓✓	✓✓✓✓
Collection of mobility / transport data	**NOx, PM, SO_2**	✓	✓✓✓✓	✓✓✓✓	✓✓	✓✓✓✓	✓✓✓✓
Air quality forecasting	**NOx, PM, SO_2**	✓	✓✓✓✓✓	✓✓	✓✓	✓✓✓✓✓	✓✓✓

4.7 Communication and engagement

4.7.1 Promotion of Park & Ride and/or Bike & Ride services

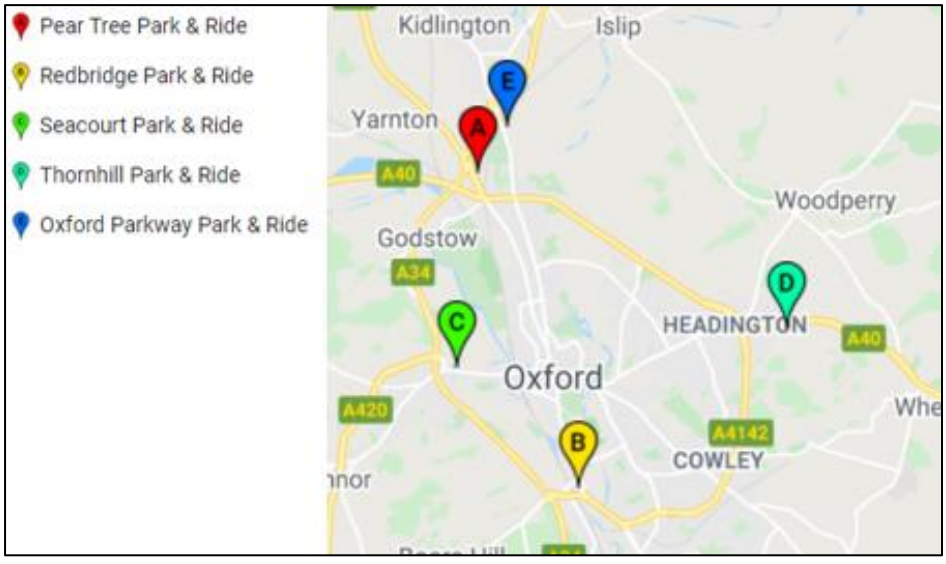
Park & Ride (P&R) and Bike & Ride (B&R) services provide a key link between private vehicles and public transport. Users are able to travel via their private car or personal bicycle to a P&R or B&R location, often on the edge of the city, and leave it in a secure location while the remainder of the journey is travelled via public transport. P&R services do not eliminate the use of the private car, however, as stations are normally outside or on the edge of the city, the pollution in the city is reduced due to fewer private cars travelling within the city. B&R services are even better than P&R services, as the entire journey is completed without use of the private car.

As mentioned above, P&R or B&R stations are usually located near to the edge, or outside of, the city. There must be room for either the car park or bicycle park, and the parking must be secure. There may be a charge to park the car / bike at the P&R / B&R station, or the charge may only be for the public transport. The above benefits can be used to promote P&R / B&R services, as can signs on roads leading towards the city which aim to divert the driver from driving directly into the city and instead choose to P&R instead.

As part of a policy toward strategic transport infrastructure, Cambridge in the UK's City Access Strategy aims to provide better bus services and expand the use of P&R. This will be undertaken by working closely with bus operators in order to provide demand management measures and/or road space reallocation, additional P&R capacity, and smart ticketing.[378] Service updates and promotion of services are provided through an information website and social network notifications, providing clear information about prices and the location of park and ride sites.[379]

Oxford in the UK has five P&R car parks available. The P&R sites are located around Oxford's ring road, each with a bus service taking passengers directly to Oxford City Centre. The locations of the sites can be viewed in Google Maps (Figure 17) and Oxfordshire County Council shows the number of available spaces in each car park in real time via the council website.[380] In 2019, one of these P&R sites was commemorated with a plaque to acknowledge it as the first enduring P&R bus scheme in the UK and a model for other cities, launched in 1973.[381]

Figure 17: Map of the five Park & Ride sites surrounding Oxford city centre[382]



[378] Cambridge City Council Air Quality Action Plan 2018 – 2023, 2019, p.26, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf
[379] Cambridge Park & Ride, http://cambridgeparkandride.info/
[380] Park and ride - the gateway to Oxford , available online at: https://parkandride.oxfordbus.co.uk/where-to-park/
[381] Blue Plaque for Redbridge P&R , available online at: https://www.oxcivicsoc.org.uk/blue-plaque-for-redbridge-pr/
[382] Park and ride sites, available online at: https://www.oxford.gov.uk/parkandridesites

In Bonn, Germany, there are around 30 B&R locations providing approximately 2,000 bicycle parking spaces.[383] Around half of the bike parking spaces are covered, meaning bikes are more secure and safe from the elements. There are also 15 P&R sites. The P&R / B&R website provides the location of all sites, the number of spaces, and whether or not there is a fee to use the service.

The city of Hamburg in Germany has an extensive network of interconnected public transport options, as described in Section 4.4.1. P&R and B&R are key to this infrastructure, offering the link between private vehicle and the public transport system, and are promoted on the HOCHBAHN (one of the main providers of bus and metro transport in Hamburg) website.[384] Promotion of P&R and B&R is beneficial for the public transport providers as it may increase the pool of users. The P&R and B&R have their own website,[385] where the processes are explained in full including the usage regulations, costs incurred, and locations via an interactive map. On the website there are also contact services, and a link to their Twitter page.[386]

One of the co-benefits of P&R services in particular is that car parking spaces within the city are freed up – this in turn reduces the amount of time spent looking for a parking space, which further reduces pollution (and is more pleasant for the driver) – see Section 4.5.4 for more information. A benefit of both P&R and B&R is less traffic in the city, which makes driving more pleasant for those who are driving in the city. Lower volumes of traffic mean (in general) less congestion, and again less pollution as the traffic flows are smooth (see Section 4.5.5). Finally, the experience of P&R / B&R can be more pleasant for the user than travelling all the way into the city via private vehicle or bicycle – completing the latter half of the journey on public transport may allow time to relax (rather than driving or cycling), eat breakfast or have a drink, and generally prepare for the day if they are commuting.

4.7.2 Promotion of EVs

The uptake of EVs is reliant on a number of factors including the price of vehicles, the charging infrastructure available, and incentives, but also on the promotion of EVs to the general public. The more people know about EVs and the more informed they feel, the likelihood of them switching to an EV is higher. In addition, the more conversations that are being had about EVs – in work, at home, with friends, the more the word is spread. It is also important to have effective information campaigns, with information that is easy to follow and doesn't overload the reader, that highlights the benefits of EVs and answers any questions or worries that people may have.

There are many ways to promote EVs, including:

- Leading by example – the city's fleet of vehicles (including cars, vans, waste vehicles etc.) are likely to be visible to the general public and they can be used to show the city is investing in EVs. It should be advertised which vehicles are EVs and the benefits that they have.
- Advertising campaigns – these may be present on buildings, billboards, or buses, on the television or the radio. They should highlight any benefits or subsidies available to those who wish to switch to an EV, and direct the user to where they can find more information.
- Websites – the department for transport / environment (or equivalent) for the city should have a page dedicated to what the city is doing with regards to EV infrastructure, what benefits are available to residents, and this should be highlighted on the homepage of the relevant department to encourage people to visit the page. If people are interested in air quality they may already check the air quality network online – this is also a good place to insert a link to EV information.
- School campaigns – educational campaigns can be useful to educate those who may buy an EV in the future, or they may go home and tell their parents about what they have learnt. It could be beneficial to highlight the specific risks of air pollution to children, and even to purchase an EV minibus for a school.

[383] Car & bicycle use, Bonn, https://www.swb-busundbahn.de/service/weitere-mobilitaetsangebote/pkw-und-fahrradnutzung/
[384] Park & Ride and Bike & Ride, HOCHBAHN, Hamburg, https://www.hochbahn.de/hochbahn/hamburg/en/home/transport/means_of_transport/bike_and_car
[385] P+R Hamburg, https://www.pr.hamburg/
[386] @ParkandRideHH on Twitter, https://twitter.com/parkandridehh

- Commercial campaigns – many commercial fleets travel great numbers of miles around a city; if these vehicles are EVs then that is an increased amount of publicity for EVs. Commercial subsidies should be brought to the attention of companies, as well as the opportunity for them to install EV infrastructure in the workplace.

In Oxford (UK), the Low Emission Strategy includes a priority target to promote zero-emission vehicles in the light duty fleet. This focuses on the promotion of electric vehicles, mainly cars, vans, and taxis, in both the business and private fleets. The aim is to facilitate a 10% uptake of electric vehicles in the light duty sector by 2020, which is projected to deliver savings of 5,000 tonnes of CO_2 and 30 tonnes of NOx annually. The project builds on existing work by the City and County Councils in their own vehicle fleets. Further development is planned in the development of charging infrastructure, introducing EVs into the municipal fleets, and working with partners such as the Low Carbon Oxford pathfinders to encourage the introduction of EVs into business fleets.[387]

The city of Hamburg in Germany has one of the best examples of EV infrastructure in Europe (see Section 4.3.3), however, the city still promotes the use of EVs via a dedicated website to electromobility.[388] Key information about the subsidies available to those who wish to purchase an EV (private or commercial) is available on the website, as described in Section 4.2.3. There are currently no state funding programs from Hamburg, therefore, the city is intensively implementing the federal government's funding programs. The funding subsidises the costs of vehicle procurement, but not the costs of using the vehicle.

The co-benefits of promoting EVs link in closely to those from incentivising cleaner vehicles (Section 4.2.3). Promotion of EVs can lead to a reduction in the cost of EVs, as the market expands due to greater uptake; this in turn can help cause reduced fuel and maintenance costs for drivers. Preferential parking policies and traffic management measures that favour EVs are likely to reduce the number of vehicles on the roads in general, which can help ease congestion in cities as well.

4.7.3 Promotion of cycling

The promotion of cycling is an important measure in encouraging the uptake of cycling. As with promotion of anything, the aim is to persuade people that cycling is the best thing for them. Increase in cycling uptake, in theory, will decrease the amount of traffic on the roads, especially private vehicles.

Promotion of cycling should focus on the benefits to the user and what opportunities they can access as a result of cycling. Any grants, freebies, money saving opportunities or other benefits should be highlighted and the relevant information about how to apply for these benefits advertised. Some people may have concerns about cycling, including safety. These concerns should be acknowledged and minimised, as described in sections 4.4.3 and 4.4.4.

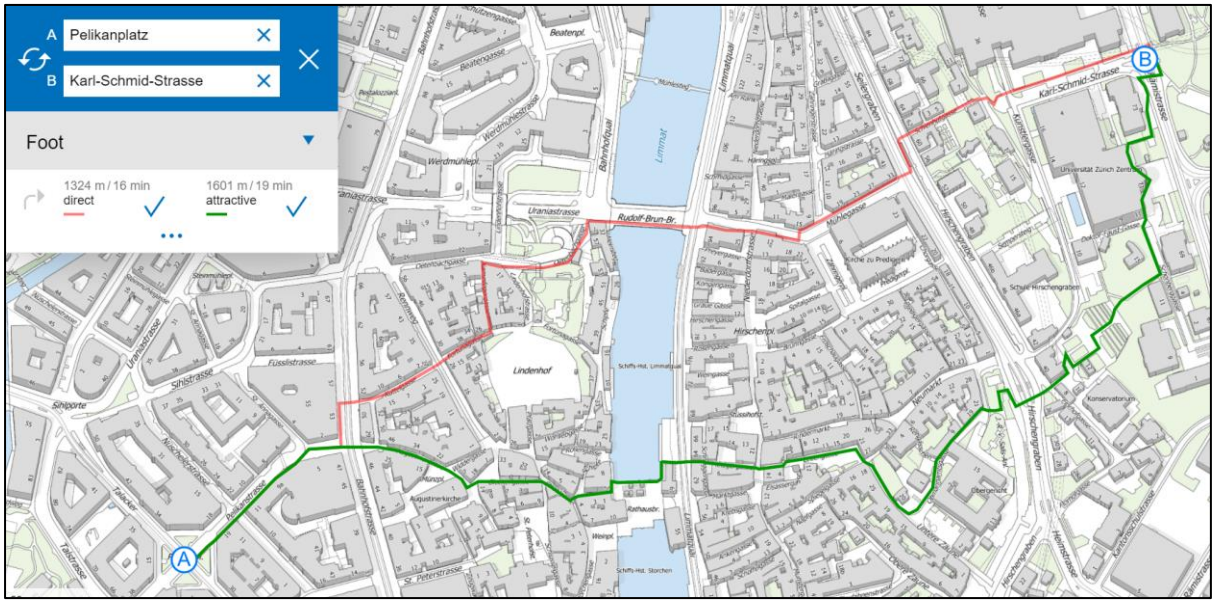
Berlin, Germany, is a city that prioritises its cyclists (see Section 4.4.4) and one of the ways of showing this is by continually promoting cycling. There are around 60 employees improving cycling matters in the Senate, the municipal infraVelo company, and in the city's districts, showing that Berlin takes cycling seriously. There are an increasing number of protected bike lanes that separate cyclists from automobile traffic and allow people to move around on two wheels without hindrance; green cycle lanes help to improve safety with their visibility and again demonstrate the importance of cycling in Berlin. The 'Alliance for Cycling' committee was also recently created to ensure that cyclists' views were included in planning and implementation of scheme that would affect them.

ZüriPlan is the bicycle and pedestrian route planner for the city of Zurich in Switzerland.[389] It has been available online[390] and via an app since 2016. The route planner allows the user to find attractive and/or short routes inside of Zurich, and many interactive "Züri z'Fuess" tours can be discovered with interesting facts and figures about the history of Zurich. An example map showing the attractive vs

[387] Oxford Low emission strategy, 2013, p.21, available online at: https://www.oxford.gov.uk/downloads/download/156/low_emission_strategy
[388] Electromobility in Hamburg, https://elektromobilitaethamburg.de/
[389] Urban Traffic Programme "Stadtverkehr 2025", Zurich, 2012, available online at: https://www.stadt-zuerich.ch/content/dam/stzh/ted/Deutsch/stadtverkehr2025/Publikationen_und_Broschueren/Stadtverkehr-Report-2012-en.pdf
[390] ZüriPlan, https://www.stadt-zuerich.ch/stadtplan

direct route options is shown in Figure 18. Expansion of the cycling network is described in section 4.4.3, and existing bicycle routes are continually being made more visible with signs and markings. In addition to this, Zurich undertakes consultative sessions and training for specific target groups and provides sources of information and products (like ZüriPlan). The city uses social networking such as Facebook and YouTube to create a dialogue with its citizens, to help engage them and get suggestions from the general public of what they'd like to see in further development of the programme. The Masterplan Velo[391] scheme outlines additional measures to promote and increase cycling. There are smaller measures like (electronic) bicycle route planners, a bicycle delivery service, the promotion of bicycles at municipal events, and subsidies for bike-to-work programmes. Zurich was aiming for an 8% share of cycling in the city by 2020, up from 4% in 2012, according to the Urban Traffic Programme "Stadtverkehr 2025".

Figure 18: Example route map using the Züriplan/Stadtplan map tool[392]



Co-benefits from the promotion of cycling include improved cyclist safety, fewer road accidents, increased uptake of active travel modes and improved health and fitness of citizens.

4.7.4 Displays of the current air quality

Promotion and public understanding of air quality data captured may help the public to become more conscious and aware of their own impact on local air quality. This can encourage change in routine behaviour, leading to improved local air quality. Evidence of public interest may also help to secure future funding for additional monitoring stations.

Most countries in Europe, and many cities, have a website dedicated to viewing air quality data online. In some cases, this can be live information – this is only likely to be available if there are continuous monitoring stations that can provide data at regular intervals. For air quality network where live information is not available, the most up-to-date information is still useful (even if it is from the previous month). It is beneficial to present information in an interesting, dynamic way, such as maps (which could be linked to the air quality index, if possible) or graphs showing trends in air quality. However, it is important to remember that if data is presented to the public, there are likely to be questions about the data and what it means. Although as much information (and FAQs) can be provided, there should also be a point of contact for the public if they do have questions.

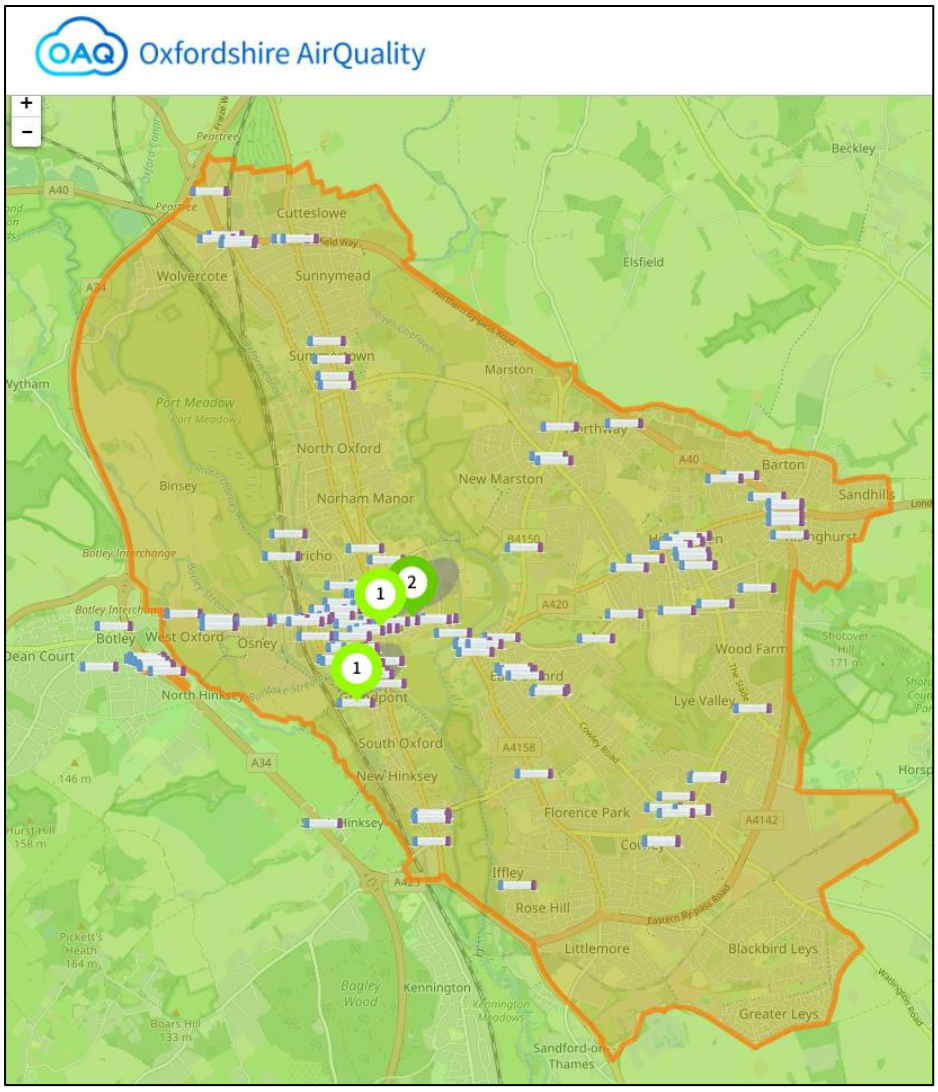
The Department of Health and Environment Zurich (Switzerland) has an official website with comprehensive background information on air quality, current pollution values, historic data, and

[391] Masterplan Velo scheme, Zurich, https://www.stadt-zuerich.ch/ted/de/index/taz/publikationen_u_broschueren/masterplan_velo.html
[392] Stadt Zurich, available online at: http://www.stadt-zuerich.ch/stadtplan

modelling scenarios.[393] Data is provided from the National Air Pollution Monitoring Network (NABEL) as well as from state and urban monitoring networks. The smartphone app airCHeck allows the current air quality in Switzerland and Liechtenstein to be viewed.[394] It also provides background information on the formation of pollutants, their sources and potential health impacts.

Oxfordshire, in the UK, has a significant air quality monitoring network in the form of diffusion tubes that are used to measure NO_2 concentrations, as well as some automatic monitoring stations that can measure a range of pollutants and provide measurements in real-time. The Oxfordshire Air Quality website provides a map of all the current and historic measurement locations in the county (Figure 19), with the most up-to-date measurement information possible.[395] For the automatic monitoring stations, live measurement graphs can be viewed, and the up-to-date Daily Air Quality Index (DAQI) value is shown. For NO_2 diffusion tubes, the most recent annual information available is displayed; diffusion tubes are a less accurate form of measuring NO_2 concentrations, so the annual mean concentration can only be provided when the results from an entire year have been validated and adjusted. The website provides information on why measuring air quality is important and how it is done, the health impacts of pollution, and what residents can do to improve air quality.

Figure 19: Map of diffusion tube locations in Oxford, and DAQI values at continuous monitoring stations in the city, as presented on the Oxfordshire Air Quality website[396]



[393] Air pollution: data, Zurich, https://www.bafu.admin.ch/bafu/en/home/topics/air/state/data.html
[394] airCHeck, https://apptopia.com/ios/app/577766644/about
[395] Oxfordshire Air Quality, https://oxfordshire.air-quality.info/
[396] Oxfordshire Air Quality, https://oxfordshire.air-quality.info/

Presenting air quality data to the public allows them to be well-informed about air quality in their area. They are then more likely to take actions to improve air quality, and therefore are more likely to see health benefits. People are often interested in graphs, diagrams, and numbers that they can ask questions about.

4.7.5 City-wide mobility campaign

Mobility campaigns generally aim to present the different options for mobility (mobility management) and encourage people to consider switching to them (travel awareness). The two themes are synergistic because increase in one will benefit the other as well; for example, increasing travel awareness will increase demand for alternative mobility services, which in turn can increase funding options to expand these services. Expansion of the services then increases the travel awareness as there are more services running, more of any one person's contacts may be using the services, etc.

Mobility campaigns rely on the ability to present information to the public and persuade them that using alternative forms of transport is a better option than using their personal vehicle. Some of the considerations may be:

- What is the current impression of alternative forms of transport in the city?
- What is the current understanding of air quality issues in the city?
- Who is the campaign trying to target? (This could be commuters, businesses, tourists.)
- The type of campaign – emotional (may rely on the impact of air pollution on people including vulnerable groups such as the elderly or children, impact on the local environment) or rational (pointing out the benefits of using another form of transport such as any monetary savings, 'extra time' during a commute, congestion, any rules/regulations e.g. LEZs.)
- Level of education provided – is the campaign just to raise awareness, or does it also aim to educate the citizens?
- Are there any 'features' of the city that can be drawn upon for the campaign? (For example, is the metro system historical, is the cycle network particularly attractive, are there any 'birthdays' that can be celebrated such as the 'birth of the bicycle' in Mannheim?)
- Are there any other cultural considerations that need to be taken?
- How will the campaign stand out and gain the public's interest? (Often a punchy name, or memorable target, are good marketing strategies.)

The "2000-Watt-Gesellschaft" project (2000-Watt Society) is an interesting project in the city of Zurich in Switzerland.[397] In 2008, Zurich established the sustainable development of the city into a 2000 Watt Society within the Municipal Code, meaning to strive for energy efficiency at every level, to reduce greenhouse gas emissions and promote the use of renewable energy. Primary energy consumption is to be reduced to 2000 watts per person, and greenhouse gas emissions to one tonne per person per year by 2050. In 2010, roughly 23% of primary energy consumption and almost 40% of greenhouse gas emissions in Zurich were attributable to traffic, therefore traffic is intended to make a significant contribution to achieving these goals. Key actions include increasing the efficiency of motor vehicles, the switch to environmentally friendly means of transport and less mobility. The annual costs for the "Mobility and living" and "Mobility for young people" programmes are expected to be approximately CHF 500,000 (approximately IND 41 million).

Berlin, the capital city of Germany, published the Berlin Mobility Act in 2018.[398] The Berlin Mobility Act plans to improve the efficiency of the transport system as a whole and supports the goal of the Berlin Senate to make car traffic in Berlin climate-neutral by 2050. 'Vision zero' is to reduce the number of road traffic fatalities and seriously injured persons to a minimum. Two of the most important measures to address road safety are to re-design dangerous junctions and create safe bicycle lanes along all main roads. From 2020 onwards, there elements dealing with pedestrian traffic and New Mobility

[397] Urban Traffic Programme "Stadtverkehr 2025", Zurich, 2012, available online at: https://www.stadt-zuerich.ch/content/dam/stzh/ted/Deutsch/stadtverkehr2025/Publikationen_und_Broschueren/Stadtverkehr-Report-2012-en.pdf
[398] Berlin Mobility Act, http://gesetze.berlin.de/jportal/?quelle=jlink&query=MobG+BE&psml=bsbeprod.psml&max=true

(carsharing, digitisation and other issues of relevance to the future) are set to be the priorities. Introduction of more comprehensive regulations for commercial transport is also planned.

Dortmund, in Germany, outlined the sub-concept "EMoDo^3 - Electromobility for Dortmund 2030" in its "Master Plan Sustainable Mobility for the City" in 2018.[399] The project provides an outlook and recommendations for strengthening electromobility in the city up to the year 2030, in order to achieve the goals of the Federal Government of Germany. The project structure is split into three focuses: charging structure and renewable energy, urban commercial transport and the municipal fleet, and individual transport and multimodal concepts. During the first of four work packages, the timetable for electromobility in Dortmund was developed and broken down into 30 measures, which will be implemented step by step following the review by the city administration. The second work package (which runs throughout the entirety of the project) identified the target groups within the three themes, in particular the commercial and municipal stakeholders. The third work package was devoted to working out the goals, target areas (hotspots), possible solutions and recommendations for action within the three themes, taking into account the results of the ongoing participation process. The first concrete measures were identified, and their implementation initiated. The fourth work package brought together all the work from the preceding three work packages into a city-wide electromobility strategy; this coincided with the urban development project "nordwärts" ("northward"), the new version of the mobility master plan and strategy concept for air pollution control.[400] In the concept study, the 30 measures were split into four categories: motorised individual traffic, local public transport, commercial transport, and cross-cutting issues. Possible development scenarios for the years 2020, 2025 and 2030 were forecast for the greater Dortmund area for each action, in order to set the targets for the EMoDo^3 electromobility concept and help prioritise the measures. This study is not the final electromobility strategy for the city, but will aid in its finalisation and enable some measures to be implemented sooner.

Co-benefits of city-wide mobility campaigns include the associated reduction in greenhouse gas emissions, as well as potential increases in tourism, and benefits to the local economy. Mobility campaigns are all about mode shift, and so reduction in private car usage will also reduce greenhouse gas emissions, giving climate change benefits. An interesting mobility campaign and good public transport system may increase tourism to the area, as it is a more pleasant place to travel in and around. In turn, this can boost the local economy whilst having a positive impact on local air quality. Mode shift to walking or cycling, even if only for part of the journey (e.g. to/from a bus stop or train station) is better for the health of residents, as is lower levels of pollution.

4.7.6 Dynamic passenger information systems (for public transport)

The collection and display of real-time public transport data in intuitively understandable (e.g. visual formats at bus stops, online or via mobile apps) can be used as an accompanying measure for informing citizens and help to influence individual behaviours.

A number of forms of communication can be used, depending on the current infrastructure in the city. Some bus stops and/or train stations may be equipped with boards that can display the information. In other cases, it may be appropriate to include live public transport information within an app that can also be used to buy / book tickets. If neither of these options are available, a QR code could be placed at bus stop locations, directing the user to a website which details the same information.

A key action from the Cambridge (UK) AQAP in 2008 was the installation of real-time public transport information at city bus stops.[401] Displays at bus stops display the bus identification (route) numbers, destinations, and estimated arrival time in minutes. The operator can make changes whilst the bus is on route, making the system as accurate as possible. Solar-powered bus timetable displays are being added, replacing previous light-emission diode (LED) displays which were powered by mains electricity. By May 2019, nine solar displays had been installed, with 12 more planned. Real-time bus information

[399] Master Plan Sustainable Mobility for the City, part of the Mobility 2030 master plan, City of Dortmund, 2018, available online at: https://www.bmvi.de/SharedDocs/DE/Anlage/K/Masterplaene-Green-City/dortmund.pdf?__blob=publicationFile
[400] Konzeptstudie Elektromobilität:„EMoDo³ - Elektromobilität in Dortmund 2030“, https://dosys01.digistadtdo.de/dosys/gremrech.nsf/(embAttOrg)/06FD4058F9DDFCB8C1258329004D5A96/$FILE/Endbericht_Elektromobilit%C3%A4tskonzept.pdf?OpenElement
[401] Cambridge City Council Air Quality Action Plan 2018 - 2023 (2019), Appendix A, available online at: https://www.cambridge.gov.uk/media/3451/air-quality-action-plan-2018.pdf

is also now available online and through a 'My Bus Trip' app,[402] which provides route maps and detailed journey information.[403]

'Moovit'[404] is a Mobility as a Service (MaaS) provider and has an app that covers a number of cities in Germany including Berlin, Bremen, Dresden, Eisenach, Hamburg, Karlruhe, Munich and Stuttgart. The company also covers other countries and many global events (such as the Rio de Janeiro Olympic Games in 2016) have made Moovit their official transit app. In India, the cities supported are listed as Ahmedabad, Bengaluru, Chennai, Hyderabad, Mumbai, Mysore, New Delhi, and पुणे (Pune). There are also 15 Mexican cities supported. The Moovit app integrates all modes of transport, including public transport, local bicycle services, ride-hailing (e.g. Uber / Lyft), scooters and car-sharing. A community of local editors ('Mooviters') provide data as well as information from public transport operators and authorities; the overall output is real-time travel information for users including the optimum route for their journey and the ability to pay for it too.

Dynamic passenger information systems for public transport make journeys significantly less stressful for citizens, especially commuters. Users can feel well-informed about their journey and with the most up-to-date information possible, make decisions about their journey should something like an accident occur. Having confidence in the reliability of the public transport system is likely to encourage further uptake in its use, as it may become preferable to the private vehicle (especially in congested cities).

4.7.7 Website for any rules / regulations relating to air quality e.g. LEZs, emissions standards, anti-idling

If rules and regulations regarding air quality are to be set for a city, and especially if bans or fines are involved, then it is important that these are set out clearly somewhere where the general public can find them. This means the public can be as informed as possible, and avoid any breaches of the rules. In addition, it allows the city to demonstrate that the rules they have set out have been communicated (in the case of any disputes / court cases relating to fines).

In 2021, the most common way for this information to be presented is online. The relevant government department (which could be the transport department, environmental department, or equivalent) should have one or more pages dedicated to explaining any rules and regulations surrounding air quality, or at least provide links to the sites where this information can be found. The information should be easily locatable from the department's homepage, or via searching (either on the government website or through a search engine). However, it is important to remember that not everyone has access to the internet or would choose to access information in that way. Therefore, other information sources should be available such as advertising campaigns, leaflets/pamphlets, helplines, etc. In essence, this information should be as easy to find and understand as possible.

Singapore has strict emissions standards for all vehicle types, as well as anti-idling and smoky vehicle enforcement. With a focus on penalties to ensure compliance, it is important that compliance information is easily accessible to the public, as well as being easy to understand. In-use vehicle emission standards (which apply to any vehicle registered in Singapore) are described in the Environmental Protection and Management (Vehicular Emissions) Regulations.[405] The website provides concise information on the emissions standards for vehicles, the requirements for smoky vehicles and an explanation of idling (including any exceptions) as well as links to accredited vehicle inspection centres where vehicle owners can have their vehicle assessed.[406] Any person who is guilty of any of the offences under the Regulations can be liable to a fine up to S$2,000 (approximately IND 109,000) and, in the case of a second or subsequent offence, to a fine up to S$5,000 (approximately IND 273,000) – this is again clearly set out online.

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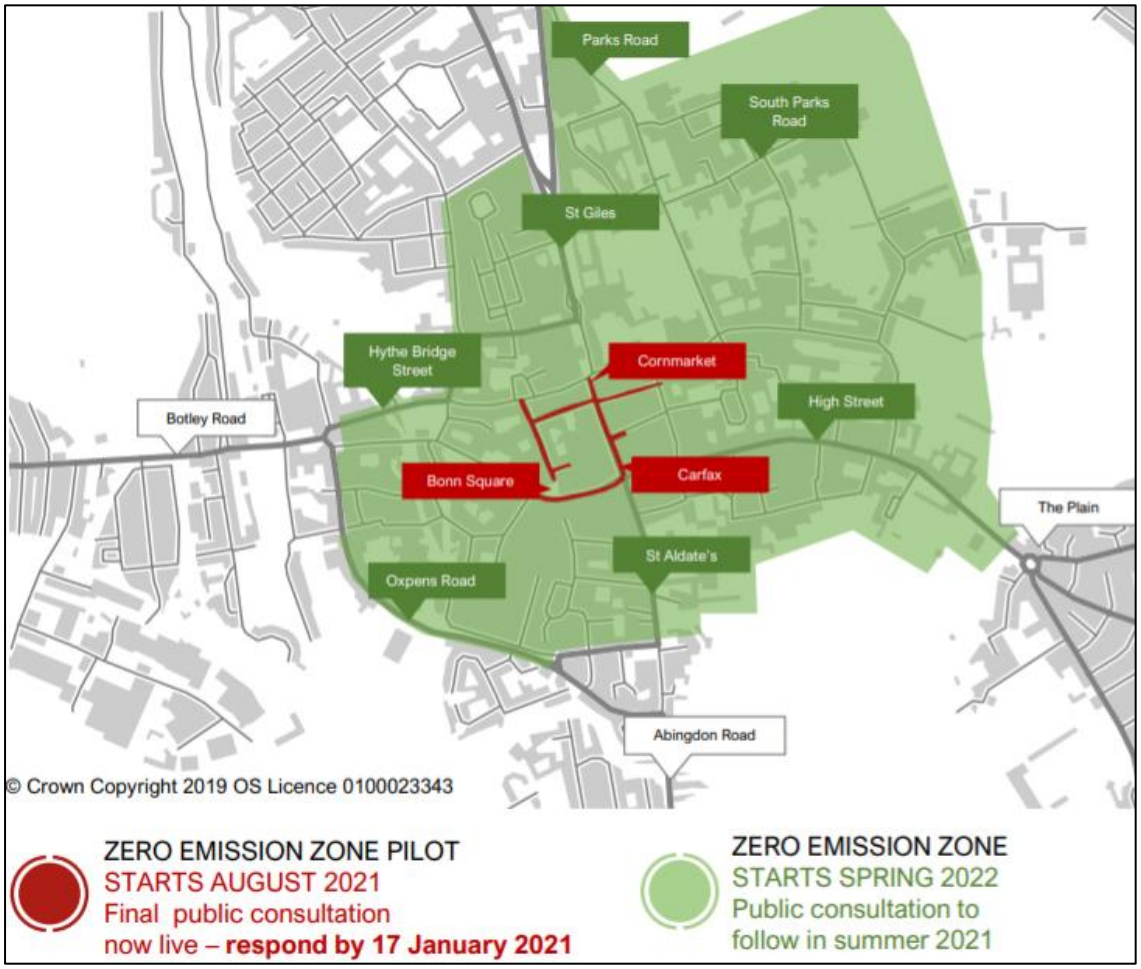
[402] MyBusTrip, Cambridge, https://apps.apple.com/gb/app/mybustrip/id526679149
[403] Real time bus information (2021), available online at: https://www.cambridgeshire.gov.uk/residents/travel-roads-and-parking/buses/real-time-bus-information
[404] Moovit, Germany https://moovitapp.com/index/en/public_transit-Germany
[405] Environmental Protection and Management (Vehicular Emissions) Regulations for Singapore (last updated in January 2021), available online at: https://sso.agc.gov.sg/SL/EPMA1999-RG6?DocDate=20120629&ViewType=Pdf&_=20200723162422
[406] Accredited Testing Bodies For Source Emission Tests in Singapore, https://www.nea.gov.sg/our-services/pollution-control/air-pollution/air-quality/accredited-testing-bodies-for-source-emission-tests

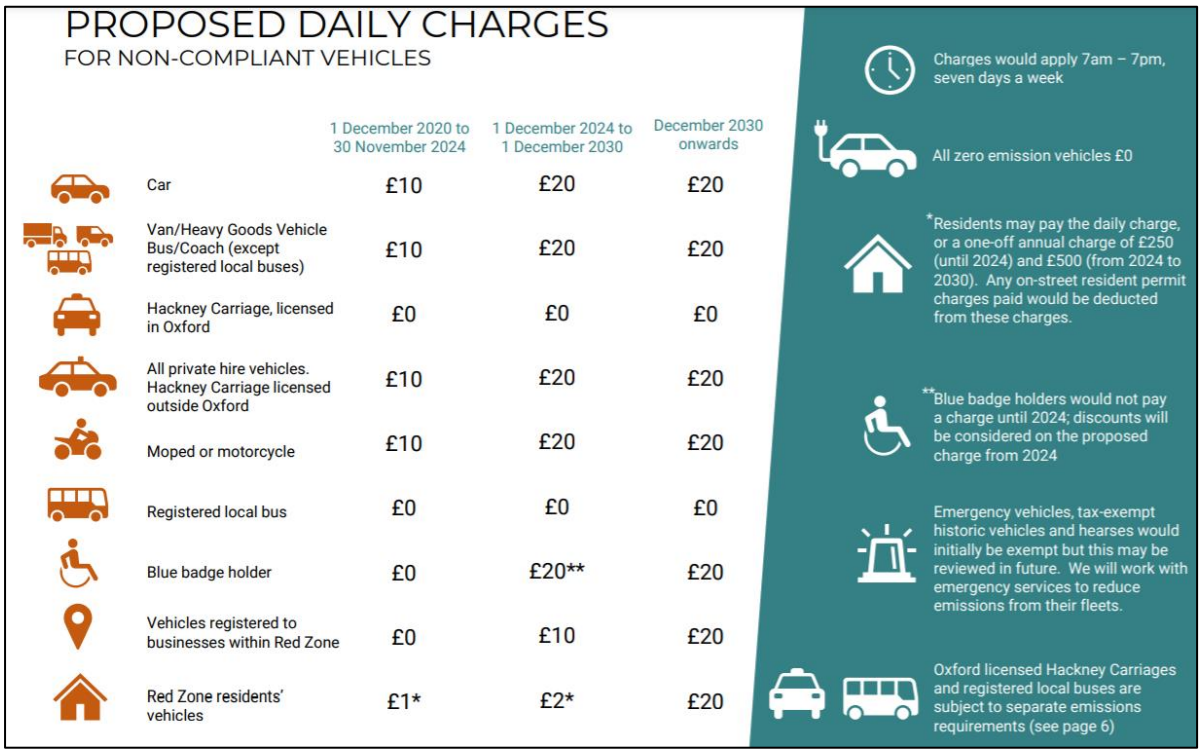
Oxford (UK) is running a pilot ZEZ from summer 2021 to early 2022 (see Section 4.1.1) to be developed and expanded throughout the city between 2020 – 2035.[407] Vehicles used in the ZEZ Pilot or ZEZ would be required to pay a charge based on their emissions, with only the 100% zero emission vehicles travelling free of charge[408]. There are plans to introduce the ZEZ to the city centre in 2022, following the pilot in 2021. The city centre ZEZ would follow the same charging system as the Pilot, but would expand the area affected as shown in Figure 20. With a ZEZ or any other type of charging scheme, it is important that those travelling to the city are aware of the scheme, the charges, and the criteria for exemptions. Even though the ZEZ is only at the pilot stage, the citizens of Oxford are able to plan for the scheme because the proposed charges are clearly outlined in the final ZEZ Pilot Proposal.[409] The document outlines the charging time period (7am – 7pm), the specific charges for different vehicle classes (including EVs, ULEVs, 'CAZ-compliant' vehicles and other vehicles), and details which vehicles would be exempt from the charges and how long for (some exemptions last for the first two years of the scheme, to allow more time for people to upgrade their vehicles). Proposed charges are shown in Figure 21. Various discounts are applied, for example to residents' vehicles, businesses' vehicles, and disabled tax class vehicles.[410]

Figure 20: Map of proposed area covered by the Oxford 2021 ZEZ Pilot and 2022 ZEZ[411]



[407] Oxford Zero Emission Zone (2020), available online at: https://www.oxfordshire.gov.uk/sites/default/files/file/roads-and-transport-connecting-oxfordshire/ZEZ_update_Jan2020.pdf
[408] Zero Emission Zone Pilot set for approval following final round of public consultation (2021), available online at: https://www.oxford.gov.uk/news/article/1739/zero_emission_zone_pilot_set_for_approval_following_final_round_of_public_consultation
[409] Oxford ZEZ Pilot Proposal, 2020, https://consultations.oxfordshire.gov.uk/gf2.ti/f/1123458/85869989.1/PDF/-/Final_ZEZ_Pilot_Proposals_20_November_2020_1301.pdf
[410] ZEZ consultation summary (2021), available online at: https://consultations.oxfordshire.gov.uk/consult.ti/formalzezpilot/consultationHome
[411] ZEZ consultation summary (2021), available online at: https://consultations.oxfordshire.gov.uk/consult.ti/formalzezpilot/consultationHome

Figure 21: Proposed charges for the Oxford Zero Emission Zone[412]



Although rules and regulations relating to air quality may be met by resistance from the general public, a benefit of displaying them clearly is that the public can feel well-informed – often a reaction to an unexpected fine is exasperated by a feeling of embarrassment and this can be mitigated by having the information beforehand. Therefore, if restrictions have to be put in place then a better relationship between the city and the citizens can be achieved by being open, honest, and keeping the public informed.

4.7.8 'Car-Free Day' and other events used for promotion

Working with residents associations and other local groups to promote awareness of air quality issues is key. Events, such as a 'Car-Free Day' can be good mechanisms for engagement and to quickly reach a large number of people.

There are many ways an event can be used to promote and educate about air quality. Events like Car-Free Day offer a certain date that can be advertised, and people can be excited about – this extra motivation can be the steppingstone between someone taking an interest in air quality issues or not. It is also effective to play on something specific to the city, such as a piece of history or an interesting road or architectural feature. As with any promotional campaign, it is important to persuade people, get them interested and get them excited about what you are promoting.

"EUROPEANMOBILITYWEEK" is the European Commission's flagship awareness-raising campaign on sustainable urban mobility.[413] Occurring annually in September, participation can be at any level from schools, to businesses, cities, to local authorities. Participating bodies are encouraged to use the week to try out innovative planning measures, promote new infrastructure and technologies, measure air quality, and get feedback from the public; one day of the week is also designated as a "Car-Free Day". In addition, there are the EUROPEANMOBILITYWEEK Awards, which award local authorities that make significant efforts to promote sustainable urban mobility during the campaign. The theme of the 2020 EUROPEANMOBILITYWEEK was 'Zero-emission mobility for all', reflecting the ambitious targets of a carbon-neutral continent by 2050, as laid out by Ursula von der Leyen, President of the

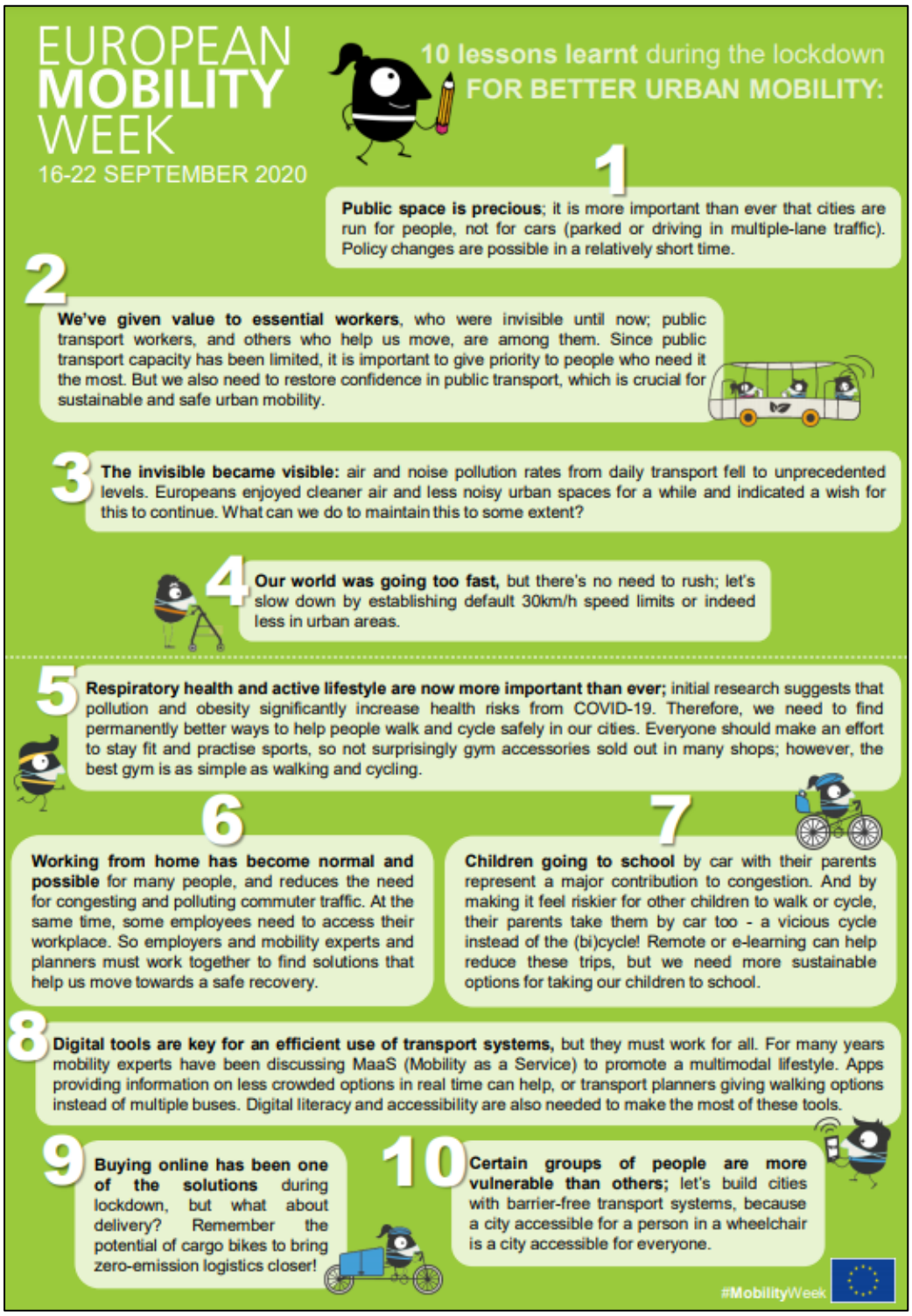
[412] Oxford Zero Emission Zone (2020), available online at: https://www.oxfordshire.gov.uk/sites/default/files/file/roads-and-transport-connecting-oxfordshire/ZEZ_update_Jan2020.pdf
[413] "EUROPEANMOBILITYWEEK", https://mobilityweek.eu/the-campaign/

European Commission, when presenting the European Green Deal. The EUROPEANMOBILITYWEEK website provides campaign resources that can be downloaded and used to promote the event as well as Car-Free Day, as well as communication toolkits and materials packages in a number of European languages. An example of the European languages available is shown in Figure 22, which shows the poster for EUROPEANMOBILITYWEEK. In 2020, EUROPEANMOBILITYWEEK even occurred completely online due to the Coronavirus pandemic. The campaign published a document explaining 10 lessons learnt during the lockdown for better urban mobility, a section of which is shown in Figure 23, which is available to view online.[414]

Figure 22: The EUROPEANMOBILITYWEEK poster with Spanish, French and German titles[415]

[414] EUROPEANMOBILITYWEEK Lessons Learnt, https://mobilityweek.eu/fileadmin/user_upload/materials/participation_resources/2020/2020_EMW_Lessons_Learnt.pdf
[415] Poster 2020, https://mobilityweek.eu/campaign-resources-for-2020/

Figure 23: EUROPEANMOBILITYWEEK resource for 10 lessons learnt during the lockdown[416]



In Jakarta, Indonesia, as part of a measure to increase public awareness the issue of air pollution, a Car-Free Day[417] has been held once a month on the busiest main road in the city centre of Jakarta. During the Car-Free Day, the road is closed to motor vehicles for six to eight hours, starting in the

[416] EUROPEANMOBILITYWEEK Lessons Learnt, https://mobilityweek.eu/fileadmin/user_upload/materials/participation_resources/2020/2020_EMW_Lessons_Learnt.pdf
[417] Infocarfreeday (2021), available online at: https://www.infocarfreeday.net/

morning on that day. This is mandated in the Air Pollution Control Bylaw of Jakarta, with organisational support from The Environment Agency, Traffic Police Department, and the Transportation Agency.

Mannheim in Germany celebrated the '200th birthday of the bicycle' in 2017.[418] Karl von Drais built the first "running machine", the predecessor of the modern bicycle, in the city of Mannheim in 1817. To celebrate his invention, and highlight its role in the current mobility system in Mannheim, the German Federal Environment Agency organised a conference in cooperation with the city administration and several other partners including the global network Scientists for Cycling. The political sphere showed strong commitment to promoting cycling and active mobility during the conference, which was a great example of using an interesting piece of the city's history to promote mobility and alternative forms of transport in Mannheim (and elsewhere).

Another way to use events to promote alternative forms of transport is to make a transport concept part of the criteria for holding a large event. The city of Zurich, in Switzerland, does just this. Events attracting greater than 5,000 people must submit a 'traffic concept' that includes provision of suitable public transport and combi-tickets for the event.[419] Even events that are free of charge have to pay a mobility charge, which is used to increase the capacity of public transport for the event.

A co-benefit of the Car-Free Day and other similar schemes is that people have the motivation to conduct various activities such as cycling, walking and other sports. Use of events for raising awareness around air quality can also have a positive tourism impact on a city, especially if the city is doing interesting things to improve air quality (such as any innovative projects). This can improve the local economy.

[418] Global cycling research and practice meet in Mannheim to celebrate the bike's 200th birthday, https://ecf.com/news-and-events/news/global-cycling-research-and-practice-meet-mannheim-celebrate-bike%E2%80%99s-200th
[419] Soot Free cities – Zurich, http://www.sootfreecities.eu/sootfreecities.eu/public/city/zurich

4.7.9 Evaluation of communication and engagement measures

The direct communication and engagement described above have been evaluated according to the criteria outlined in Section 4. Table 8 provides a summary of the results.

Table 8: Evaluation of communication and engagement measures

Measure	Evaluation according to criteria						
	Which pollutants are impacted?	Air quality impact (1-5)	Costs (1-5)	Co-benefits (1-5)	Reliance on other measures (1-5)	Innovation (1-5)	Prospective timescale (1-5)
Promotion of Park & Ride / Bike & Ride	**NOx, PM**	✓✓✓	✓✓✓✓	✓✓✓✓✓	✓	✓✓✓	✓✓
Promotion of EVs	**NOx, PM**	✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓	✓	✓✓✓✓✓	✓✓✓
Promotion of cycling	**NOx, PM**	✓✓✓	✓✓✓✓	✓✓✓✓✓	✓	✓✓✓	✓✓✓✓
Displays of current / future air quality	**NOx, PM, SO_2**	✓	✓✓✓✓	✓	✓	✓✓✓✓	✓✓✓✓✓
City-wide mobility campaign	**NOx, PM**	✓✓	✓✓✓✓	✓✓✓✓✓	✓✓	✓✓✓✓	✓✓✓✓
Dynamic passenger information system	**NOx, PM**	✓✓	✓✓✓✓✓	✓✓✓✓✓	✓✓	✓✓✓✓✓	✓✓✓
Website for rules / regulations relating to air quality	**NOx, PM, SO_2**	✓	✓✓✓✓	✓✓	✓	✓✓✓	✓✓✓✓✓
'Car Free Day' and other promotions	**NOx, PM**	✓✓	✓✓✓	✓✓✓✓	✓✓	✓✓✓✓	✓✓✓✓

5 Governance and monitoring

This section outlines key considerations for effective design, delivery, and monitoring/validation of transport-related air quality improvement measures. This will include consideration of delivery in terms of potential funding mechanisms. This information has already been applied using a matrix approach (with criteria described in Section 4) to characterise each candidate measure in terms of governance, delivery, and monitoring, in the evaluation sections at the end of each set of measures.

5.1 Governance

The governance of measures to improve air quality concerns the structure and processes for decision making, including the assignment of contracts, allocation of funding, accountability, and regulation.

Air quality improvement measures should fit into an appropriate, possibly already existing, strategy where this is possible. Incorporating measures into an overarching strategy with a clear purpose will enable confirmation that the measures represent an effective investment of public funds.

Transparency is a key pillar of good governance. Evidence of appropriate spend of funding is important to gain the confidence of the general public in the actions that are being taken by the government. Although it is interesting and exciting to fund innovative projects, it is important to consider when the benefits from these projects might actually be realised. If a large proportion of funding is spent on innovative projects that will take years to implement and see no benefit to air quality for a number of years after, then the amount of funding against a less innovative, but 'tried and tested' measure that will see immediate benefits needs to be properly weighted.

Evidence of competitive tendering again reinforces transparency of the governance of implementing air quality measures. It should be demonstrated that the best overall tender has been awarded each contract – not just the cheapest price or the bidder with the best connections. Competitive tendering allows the public to be assured that the best people or company have been selected for the job and again that funds are being spent appropriately.

Evidence should be provided that investments will be effective for the long term. For example, when considering emissions standards, appropriate maintenance/servicing contracts for vehicles must be awarded. If a significant amount of money is being invested in EV infrastructure, then considerations for the long term might include the types of chargers installed, as the slower chargers may become obsolete in the future. The provision of chargers for different types of vehicles, and their location within the cities also must be considered, taking into account where future development in the cities will be and how this is likely to change travel patterns.

5.2 Monitoring

Monitoring the impact of measures to improve air quality cannot simply be done by tracking the change in pollutant concentrations at different locations. When multiple measures to reduce emissions from transport are being implemented at once, it is impossible to tell which measures are having what scale of impact on air quality. Therefore, it is important to consider a range of monitoring techniques that assess both the measures' impact on air quality, but also other effects.

With regards to any type of monitoring, it is vital to gather baseline data before implementation of a new programme. Without baseline data, it is impossible to determine the impact of a measure as the difference between the original situation without the measure and the current situation with the measure in place cannot be calculated. Baseline data should ideally be collected over a long period of time, in order to take into account differences such as: the difference between peak traffic and off-peak traffic (daily), weekday and weekend traffic, changes in weather, and changes in season (including tourism seasons where appropriate). By incorporating all of these factors and using a long averaging time for the baseline situation, as well as the situation with the air quality measure applied, the true impact of the measure can be quantified.

One of the simpler types of air quality measure to monitor is vehicle emissions testing and rectification of problems identified. This is because the way the measure needs to be set up, with rigid requirements

for regular emissions testing (e.g. through PUC centres) and following up with vehicles that do not meet emissions standards. In theory, the regulation of emissions standards should allow for monitoring of the measure because all emissions testing and issues, as well as their resolution, should be recorded when the testing is carried out. Therefore, important monitoring statistics such as the number of vehicles tested, the number / proportion of violations, the types of violation, and the number of fines issued, should be easy to keep a track of and publish at regular intervals.

To track deployment of new technologies, for example the use of new public transport resources, there are a few methods that can be used. Section 3.6.2 outlined examples of mobility / transport data collection. These types of surveys and data collection methods could be used to monitor mode shift, for example, although their reliability (especially for surveys) is questionable. The use of cameras, such as ANPR studies, can be a good way to determine the fleet mix and how that changes over time – although most campaigns are only a few days long and so the fleet will only be representative of that day. For transport modes that require a ticket or an app in order to use them, then data should be available from the relevant companies as to the volume of people on each mode of transport. This data is also likely to be available for a range of time periods, for comparison.

Finally, it is possible to design some air quality monitoring programmes in a way that picks up the effects of specific measures. It may be appropriate to review air quality monitoring data in the light of measures implemented, to determine effectiveness. For example, monitoring stations might be better placed at locations identified as likely pollution hotspots, such as congested roads where measures are targeting. It may also be appropriate to carry out a short-term low-cost sensor monitoring campaign in order to determine where the pollutant hotspots are, before relocating or installing more monitoring stations. Use of advanced techniques for data analysis to identify any systematic changes in air pollution levels may be applicable following implementation of specific measures.

The success and impacts of the actions presented in this report can be tracked through a process of Monitoring, Evaluation and Reporting (MER). This will allow the implementing authority to track and review the progress against the set targets. This process should be underpinned by key performance indicators and a framework for regular monitoring, impact evaluation and progress reporting. This will provide stakeholders with transparency about the process, inspiring trust in the city government and its commitment to improving air quality.

A well-functioning MER system improves the accountability and transparency of the diverse range of actors involved in delivering an air quality action plan and can also help cities to secure further support for action from other levels of government, and from key stakeholder groups in the city.

The process can build on already existing governance structures. It should consider who will contribute to the day-to-day development and maintenance of the MER system, the delivery structure and the resources needed.

6 Conclusions and next steps

This report sets out a comprehensive list of examples of best practice for managing emissions and achieving improvements in air quality. The findings from the review have enabled us to identify specific individuals/partners in cities in Germany and the UK to interview, to provide more in-depth understanding of key success factors for effective interventions, and those that may be recommended for implementation as part of the Triangular Cooperation Project. The recommendations will be further tailored to reflect the specific needs and capabilities of the cities, through discussions to be held during the Best Practice Exchange and Reporting Session.

On the basis of the review, is it expected the following cities will be asked to share their experiences and expertise on air quality management with the partner cities in Mexico and India:

Hamburg, Germany

Hamburg is the 'gold standard' in terms of air quality measures and associated infrastructure. Hamburg has a well-established EV charging infrastructure, including public transport as well as private vehicles. The most recent “Master Plan for Designing More Sustainable and Emission-Free Mobility in Hamburg” contains further measures to expand electromobility, such as continued expansion of the electric bus fleet and procurement regulations for other modes of transport (e.g. delivery vehicles). Of particular interest is also the bilateral mobility partnerships that have been agreed with Volkswagen, BMW, Daimler, T-Systems, Deutsche Bahn and HERE Technologies, as well as Hamburg’s role as host of the Intelligent Transport Systems World Congress in October 2021 and the projects associated with this.

Berlin, Germany

Berlin has a wide range of measures that contribute to air quality improvements and demonstrate best practice in their respective fields. Berlin’s state-of-the-art traffic control centre (Verkehrsregelungszentrale, VKRZ) is responsible for monitoring and manually activating traffic light systems at 2,000 intersections in Berlin, for operating nine Variable Message Sign systems on motorways, for monitoring the traffic situation on over 1,500 km of roads, and for transmitting traffic information from the regional reporting office – these actions all help to keep the flow of traffic in the capital smooth, and reduce transport emissions. Another area of interest is cycling; Berlin has improved the cycling infrastructure through large increases in funding, and demonstrated the importance of cycling by increasing cyclists’ representation in the Senate. There are an increasing number of protected bike lanes that separate cyclists from automobile traffic – these green cycle lanes help to improve safety with their visibility and can be quickly installed. Another interesting measure is the use of e-cargo bikes for ‘last mile’ delivery, which was trialled during a temporary project (KoMoDo); approximately 120 e-cargo bikes are now available to rent under the ‘fLotte kommunal’ scheme run by the German Bicycle Club Berlin e.V. (ADFC Berlin).

Reutlingen, Germany

Reutlingen in Germany was selected as one of five model cities that the German Federal Environment Agency would support with additional funding to the "Immediate Clean Air Program", following an extensive review of the cities' AQAPs. There are a number of interesting measures outlined in the Green City Plan for Reutlingen, some of which have been in place for a number of years and others which are proposed for the near future. The city has an established dynamic traffic management system (since 2007) and parking guidance system (since 2005), both of which have further improvements planned. The 'truck route concept' combines banning trucks from certain routes with support for HGV owners/drivers and is an innovative solution to one of the more polluting vehicle types. Reutlingen also has plans to expand the EV infrastructure to support an increased number of EV buses, private vehicles and an electric carshare fleet. Additional measures to promote public transport such as provision of Wi-Fi, driver training (for greater efficiency) and even automated vehicles may be of interest to the Indian cities.

Mannheim, Germany

Mannheim in Germany was also selected as one of five model cities that the German Federal Environment Agency would support with additional funding. The city has a significant focus on improving

the share of cycling. A successful cycling strategy has been in place since 2010, achieving a 5% increase in cycling within three years, and further increases were targeted for 2020. Mannheim is the birthplace of the "running machine" (predecessor to the bicycle) and celebrated the 200th birthday of the bicycle in 2017 – a great example of using events to promote alternative forms of transport. Mannheim also presents an interesting method statement including the use of 'central traffic hubs as mobility stations' where various types of public transport are linked, as well as cycle paths, footpaths, and potentially other forms of mobility.

Oxford, United Kingdom

Oxford provides an example of high-standard air quality practices in the UK. The city has developed a range of measures as part of their Low Emission Strategy to support air quality improvements, notably in the areas of freight traffic management, expansion of zero emission vehicle uptake and developing public transport. Oxford City Council has installed electric charging points in and around the city to encourage use of electric vehicles. Another key measure for Oxford is the current pilot Zero Emission Zone.

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