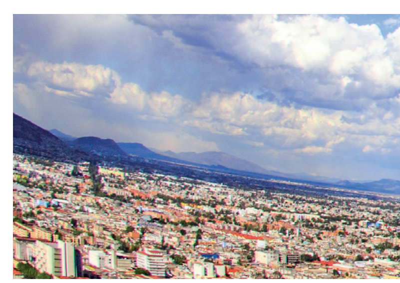
International Transport Forum

Strategies for Mitigating Air Pollution in Mexico City

International best practice



Case-Specific Policy Analysis

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Strategies for Mitigating Air Pollution in Mexico City

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The International Transport Forum

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Case-Specific Policy Analysis Reports

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Abbreviations

AQG	WHO Air Quality Guidelines
AAQD	EU Ambient Air Quality Directive, Directive 2008/50/EC
AQI	Air Quality Index
BAR 90	US Bureau of Automotive Repair vehicle inspection test using 1990 criteria
CAF	Development Bank of Latin America
CAM	Metropolitan Environmental Commission
CAMe	Environmental Commission for the Megalopolis
CIVAR	Mexico City Remote Inspection and Surveillance Center
GDI	Gasoline direct injection
HNC	*Hoy No Circula* (No-Driving Days)
ICCT	International Council for Clean Transportation
IMECA	Air Quality Index
INECC	National Institute of Ecology and Climate Change
ITF	International Transport Forum at the OECD
LEZ	Low emission zones
NAFIN	*Nacional Financiera* (development bank)
PCAA	Environmental Atmospheric Contingency Program
PICCA	Comprehensive Program against Atmospheric Pollution
PIREC	Comprehensive Program of Pollutant Emissions Reduction
PM	Particulate matter
PROFEPA	Federal Attorney's Office for Environmental Protection
PROAIRE	Air Quality Improvement Programs
PVVO	Mandatory Vehicle Inspection Program
OBD	On-board diagnostic system
SCR	Selective catalytic reduction
SEDEMA	Ministry of Environment of Mexico City
SEMARNAT	Ministry for the Environment and Natural Resources
SIMAT	Atmospheric Monitoring System for Mexico City
SIVER	Mexico City Vehicular Inspection Information System
WHO	World Health Organization
ZMVM	Metropolitan Area of Valle de México

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Executive summary

Background

Air quality has improved substantially in Mexico City since the 1980’s but the city experiences regular episodes of ozone and particulate matter concentrations in the air that exceed health limits. The geography of the conurbation, situated in a bowl surrounded by mountains, frequently traps air over the city allowing pollutants to accumulate. Updating of pollution alert limits in 2012 and 2014 to reflect international health standards revealed the full extent of the problem. In the first half of 2016 the Metropolitan Zone of the Valle de Mexico (ZMVM) experienced 115 days of ozone concentrations above the acute exposure health limit, with 16 days exceeding pollution alert levels. This led to the implementation of temporary restrictions on the use of vehicles, extended through to July. The ozone alerts and particulate concentrations in the air that frequently approach health limits underline the need for updating and adding to existing emissions control and traffic management policies.

The air pollution exposure health limits that apply in Mexico City are in line with World Health Organization (WHO) guidelines and similar to those adopted elsewhere in North America and in Europe. Regular breaching of the limits is not confined to Mexico. There are 43 designated Non-Attainment Areas for ozone in the USA under National Ambient Air Quality Standards, classified as extreme in the Los Angeles South Coast Air Basin and the San Joaquin Valley. An increasing number of European cities record air pollution in excess of EU standards and many large cities in Asia experience severe pollution episodes. Policy frameworks have been developed in the USA and Europe to require cities in regular breach of standards to take special measures to cut emissions, with recourse ultimately to financial penalties if improvements are insufficient.

Against this background of common problems, the International Transport Forum (ITF) at the Organisation for Economic Co-operation and Development (OECD) and the Development Bank for Latin America (CAF) together with the Ministry of Environment of Mexico City (SEDEMA) convened a workshop for regulators and policy makers in Mexico City and the surrounding Metropolitan Zone in January 2017 to discuss air pollution mitigation strategies with their peers in other major cities and with experts on vehicle emission control technologies. The objective was to provide insights into the most effective short- and long-term options on the basis of international experience. This report presents the findings of the workshop together with the reports prepared for it on air pollution and mitigation strategies in Mexico City and recent findings of research into emissions from vehicles in real-world driving conditions.

Findings

Mexico City and adjacent municipalities in the Metropolitan Zone of the Valle de Mexico have developed stringent air pollution mitigation measures with a fairly comprehensive set of measures similar to policies developed in some cities in other OECD countries. Pollution is generated by a wide range of industrial and other activities. Emissions of volatile organic compounds from non-mobile sources remain a key factor in the formation of ozone in the Valle de Mexico but as in all large cities, substantial reductions in emissions from road vehicles are a key strategy for achieving clean air.

The factors that drive excess emissions from vehicles in the real-world traffic conditions of the city are critical to determining priorities among the potential measures available to mitigate air pollution. In Mexico City, traffic is dense and frequently heavily congested. Average speeds are low and stop-go conditions standard. Emission control technologies must be effective in these conditions if they are to be of relevance to improving the air of the city. Diesel emission control technologies in particular have had a poor record in cutting emissions in these circumstances. The latest generation of standards for heavy duty vehicles (US EPA 2010 and Euro VI standards for heavy duty vehicles) and the monitoring and control systems they require represent a major advance. Early results of testing on the road suggest that unlike previous control systems they perform as well in the real world as in laboratory testing for type-approval.

Traffic management measures to achieve more fluid conditions, including by restricting the number of vehicles on the road, are the other main approach to mitigating emissions. In the short term, reducing speeds on motorways and trunk roads in the metropolis is the single most effective measure for cutting air pollution available to State governments. Emissions rise steeply at higher speeds and enforcing a maximum 80 km/h limit cuts emissions significantly. Lower limits also tend to make traffic more fluid and increase the overall capacity of the road and variable speed limits are employed in many cities to manage congestion. Introducing efficient parking prices is central to reducing traffic flows and encouraging modal shift towards public and non-motorised modes.

Restrictions on the use of vehicles are a key part of the emergency response to pollution alerts in the Metropolitan Zone of the Valle de Mexico. These are based on Mexico City’s strict vehicle inspection and maintenance programme, which relies on best-practice techniques of exhaust emissions testing, including checks of the on-board diagnostics system, similar to the approach used in California. Restrictions on vehicle use depend on the certified emissions class of each vehicle after inspection. The system is also employed to restrict the use of more polluting vehicles on a routine basis one day a week and on Saturdays. Exemptions from restrictions provide a strong incentive for the purchase of cleaner vehicles. Vehicle ownership taxes should similarly be differentiated by emissions class.

Providing good quality public transport services as an alternative to the use of private cars and taxis is an essential complement to measures that restrict or charge for the use of private vehicles. The programmes developed for coordination, reform and investment in public transport across the ZMVM need to be pursued as a matter of urgency.

A range of measures should be taken to cut emissions and improve air quality the ZMVM and an integrated approach is advisable. The following recommended actions cover the main areas for intervention; a more disaggregated and complete list of recommendations is developed at the end of Chapter 1, identifying the responsible authorities in each area.

Recommendations

Consolidate the use of on-board diagnostic system checks in the mandatory vehicle inspection and maintenance programme

On-board diagnostic (OBD) system checks are an important tool in the emissions testing procedure under the mandatory vehicle test, inspection and maintenance programme in Mexico City together with tailpipe exhaust gas testing. Both tests are required because of the greater effectiveness of OBD interrogation in detecting deficiencies, diagnosing faults and avoiding fraud, whilst dynamic tailpipe exhaust testing will catch problems invisible to OBD checks, ensure that emissions are within the current limits and also provides the default test for those vehicles that do not comply with current OBD requirements or are not equipped with OBD (of course only vehicles equipped with OBD should be eligible for certification in the cleanest vehicle categories).

The Ministry of Environment of Mexico City has submitted evidence on the importance of both tests to achieving the environmental objectives of the law on inspection and maintenance to defend the test procedure in court, where it has been challenged on constitutional grounds. As recent court rulings undermine the test and inspection system, further evidence including the present report should be made available to the judiciary. At the same time, the Federal Ministry of Environment (SEMARNAT) should take legal action against car manufacturers and distributors that fail to ensure vehicles are equipped with an operational OBD system, which has been required by law for new vehicles since 2006.

Improve the mandatory vehicle inspection programme to include mechanical roadworthiness checks and to measure ultrafine particulate emissions

The condition of tyres, clutches, brakes and other mechanical components is important for both emissions controls and safety. The particles emitted by wear processes are toxic and may account for as much as half of all PM10 emissions from vehicle use. Including mechanical checks in mandatory vehicle inspections will create a maintenance culture that will improve air quality. It is also important to control ultrafine particulate emissions. Measurement of particle numbers should be included in tailpipe exhaust gas testing in anticipation of future vehicle emissions regulations and to monitor the impact of gasoline direct injection technologies on the severity of particulate matter pollution.

Adopt state-of-the-art emissions standards for heavy duty diesel vehicles without delay

Mexico City already incentivises the use of the latest generation of trucks and buses by exempting them from the restrictions on use introduced to manage air pollution. The standards should be adopted nationally for all new vehicles without delay. The Federal Environment Ministry has proposed adopting EPA 2010 / Euro VI emissions standards for heavy duty vehicles for introduction in 2019. A decision has been delayed while the potential value of transitioning through Euro V standards is assessed. Given the very small reductions in emissions achieved in practice on the road by Euro V standards in Europe and the very large improvement achieved with Euro VI standards, the deliberations should conclude rapidly that a transition through Euro V standards would be counterproductive and Euro VI standards should be agreed on without further delay for implementation as early as possible.

Verify vehicle emissions in real world driving conditions

As the recent research on emissions from light and heavy duty vehicles in real world driving conditions summarized in this reports make clear, emissions in typical urban conditions can exceed levels proscribed in type approval standards many-fold. High altitude also has a strong non-linear influence on emission and some advanced engine and emissions control technologies might be more sensitive than older models. It is important to understand the impact on mitigation measures. Verification of emissions from vehicles meeting US EPA and Euro standards at altitudes typical of Mexico City should be undertaken by Mexico City, the Mexican Petroleum Institute or other pertinent institution as a matter of priority. In principle the in-use conformity regulations adopted in the latest Euro emissions standards are the approach to addressing anomalies related to altitude but this should be confirmed with experimental evidence.

Continuously update the system of restrictions on vehicle use in the Metropolitan Zone of the Valle de Mexico and improve enforcement

Further differentiation of restrictions should be introduced to incentivise purchase of cleaner light duty vehicles. The latest light duty vehicle emissions standards (EPA Tier 3 / Euro 6) should be used as reference values ahead of their incorporation in national standards so that at an appropriate point in the future the highest environmental class certification is awarded only to these vehicles. Reciprocal arrangements for enforcement and collection of fines for contravening restrictions should be agreed between the States participating in the Environmental Commission for the Megalopolis (CAMe) as whereas vehicles in contravention of the rules can be fined by any of the jurisdictions collection of the fine is not automatically pursued across borders.

Phase in a city-wide low emissions zone

The current Hoy no circula system of regular restrictions on the use of more polluting vehicles could be complemented, and perhaps replaced in the long term, by a city-wide low emissions zone, using the existing vehicle inspection, classification and identification system. In principle a low emission zone would have a bigger potential for reducing emissions as the incentives for using cleaner vehicles and switching to other modes of transport would apply every day. Preparations for introduction of a low emission zone are recommended, with studies to examine practical implementation issues. The initial focus would be control of heavy and light duty freight vehicles. Should a generalised low emission zone be introduced, the current system of additional restrictions during pollution alerts (PCAA) would need to be remain in place.

Differentiate the tax on vehicle ownership to provide incentives for cleaner cars

The annual *tenencia* tax on vehicle ownership should be differentiated on the basis of the emissions characteristics of the vehicle rather than its value. This would provide incentives to purchase cleaner vehicles in every segment of the market. The six States that cooperate in the CAMe should end exemptions to the tax (qualified as subsidies in Mexico) and consider earmarking revenues to investment in public transport. This should improve acceptance of this tax as well as generating a revenue stream to support alternatives to the use of the car.

Introduce incentives for ultra-low sulphur diesel and gasoline at national level

Regardless of technology, improving fuels reduces emissions from every vehicle on the road and incentives to use ultra-low sulphur diesel and gasoline, both of which are available in the metropolis, are a way to achieve to cut emissions from all vehicles. International experience suggests that tax differentiation to ensure that the price at the pump of ultra-low sulphur fuels is competitive would produce a shift to 90% clean fuels in the space of one or two years.

Reduce speeds on motorways and ring roads

Speed limits produce immediate reductions in emissions at very little cost. The 80 km/h speed limit on urban motorways and ring roads introduced in Mexico City in 2015 should be adopted across the Metropolitan Zone of the Valle de Mexico and enforced to ensure vehicles operate more often in the 50 to 90 km/h range in which emissions control technologies work best. Limiting speeds to below 80 km/h also helps maintain free flow traffic for longer as congestion builds.

Manage parking more effectively and consider road pricing

Extending the Ecoparq programme of charges for on-street parking throughout the Metropolitan Zone of the Valle de Mexico is an important step to establishing an effective strategy for managing traffic. Moving from fixed to differentiated parking rates will be necessary to better reflect the value of public space in different areas (according to demand and land-use) and incentivise modal shift in areas that are well served by public transport and have good facilities for cycling. Parking space regulations should set an objective of reducing supply where density and land-use mix is high and public transport, walking and cycling facilities are available. Abolishing minimum requirements for off-street parking in building codes is in line with actions taken by other world cities that seek to move away from car-oriented development and achieve more transit-oriented development patterns. Specific mechanisms to reduce congestion are also needed. The more widespread use of on-road parking charges is an effective tool for this together with road pricing and congestion charges and their potential for practical implementation should be evaluated.

Improve sustainable transport alternatives to cars and taxis

Provision of good quality public transport services is essential to the success and acceptability of restrictions on the use of vehicles. Measures to improve strategic planning and coordination of public transport services as set out in the PROAIRE programme should be pursued as a matter of high priority. This includes reform of bus concessions throughout the Metropolitan Zone of the Valle de Mexico and where agreements are made to scrap microbuses and operate routes under consolidated concessions with higher standard vehicles, ensure the old vehicles are actually scrapped and do not continue to be used in competition with the new services. Investments in metro and BRT systems have proved effective. The programme of investments underway in improved metro and BRT station access and protected walking and cycling infrastructure is an important part of the package and should continue.

Consolidate initiatives to integrate land-use and transport planning

For the long term more integrated land-use and transport planning is essential to containing air pollution. Planning tools to assess the impact of development on traffic and fund necessary enhancements to public transport have been introduced in Mexico City but these now need to be linked explicitly to planning consents. The property development mobility impact assessment procedure provided for under Mexico City's 2015 Mobility Law needs to be implemented fully and linked directly to the process of awarding construction authorisations. This planning framework for ensuring developers contribute to investment in public transport should be extended across the Metropolitan Zone of the Valle de Mexico and other options for diversifying funding for investment in public transport explored. A Mobility Master Plan for the Zone, linking funding allocation to priorities established jointly by the State and Federal authorities should be established. The CAMe appears to be the most effective regional institution available to establish such a plan.

Improve retrofit programmes with inspection, maintenance and quality certification

Pilot programmes to retrofit buses in Mexico City with diesel particulate filters are reported to be successful and have been extended. An inspection and maintenance regime should be introduced to ensure that filter efficiency is preserved in use and any clogging problems are addressed properly and not simply by removing filters. The programme of subsidies to replace3-way catalytic converters on cars failing inspection and maintenance tests should be backed by a quality and durability certification system for the replacement parts.

Introduce emissions regulations for off-road vehicles and mobile machinery

Construction machinery for buildings, roads and so on is currently unregulated. These are a significant source of emissions. Emissions controls for new vehicles and machinery along the lines of EU regulation 2016/1628 should be introduced. The development of restrictions on use of this machinery should be considered for pollution alerts.

Invest more in communicating with the public on the development of new anti-pollution measures

Ensuring support for air pollution mitigation measures, and particularly those that restrict the use of vehicles, begins with information campaigns to raise awareness of the health risks of contaminated air and the steps that individuals and government can take to reduce exposure to pollution. Proposals for new measures should be subject to public consultation. Data on the effectiveness of measures taken should be disseminated on a regular basis through public reports.

1. Air pollution mitigation strategies

Air pollution mitigation priorities in Mexico City

Pollution is generated by a wide range of industrial and agricultural activities. The pollutants of most concern vary by location and concentrations in the air are sometimes determined more at regional or hemispheric level than locally. But in all large cities, substantial reductions in emissions from road vehicles are seen as a key strategy for achieving clean air.

The health effects of excess concentrations of particulate matter (PM), nitrogen dioxide (NO_2) and ozone (O_3) are outlined in Box 1.3. PM and O_3 concentrations are the main concern in the Metropolitan Area of Valle de México (ZMVM).[1] Whilst O_3 is less toxic than some particulates, excess concentrations irritate the respiratory tract and greatly exacerbate the inflammation provoked by particulate pollution and allergens in the air. NO_2 has similar effects to ozone.

In Mexico City, the central part of the metropolitan area, it is estimated that if the WHO recommendations on air quality were observed more than 1 400 deaths per year could be avoided. These deaths cost around MXN 30 billion (Mexican pesos) to society (INECC, 2016b).

Mexico has set national ambient air quality standards for O_3, NO_2, sulphur dioxide, carbon monoxide and particulate matter (PM_{10} and $PM_{2.5}$). These are similar to standards in the US and Europe (Tables 1.1 and 1.2). Legislators in the EU have basically adopted the WHO guidelines, with a degree of tolerance permitted in some cases for the time being (EEA, 2016). In cities where the levels are exceeded more often than the tolerated number of days, national governments are required to take remedial action. This follows the approach originally adopted in the US where areas that do not attain National Ambient Air Quality Standards ultimately face withholding of federal funds.

The Metropolitan Area of Valle de México has defined an air quality index (AQI) to characterise air pollution. This follows the methodology developed first in the US. Mexican and US air quality bands and pollution thresholds for O_3 and PM_{10} are summarised in Table 1.3. One hundred points on the AQI corresponds to national health limits for acute exposure.

In the ZMVM, 150 points on the AQI is the threshold for issuing emergency pollution health alerts. Since April 2016, this is the level for alert phase 1 and corresponds, for O_3, to an hourly average concentration of 155 ppb and for PM_{10} to a 24 hour moving average of 215 $\mu g/m^3$. These legal limits are regularly exceeded and action therefore must be taken to reduce emissions. In the European Union, attention has focussed on ozone (hourly average alert threshold 240 $\mu g/m^3$), NO_2, sulphur dioxide and PM. For PM, the EU regards no level of exposure as safe. The O_3 alert threshold in the ZMVM (equivalent to 310 $\mu g/m^3$) is 29% higher than the EU limit and the PM_{10} threshold over four times higher than the *defacto* EU limit (Table 1.2). In the USA alert thresholds vary from city to city.

Box 1.1. **Air pollution chemistry**

Mobile sources contribute 79% of NO_X, 21% of PM_{10}, 20% of VOC and 96% of CO emissions in the ZMVM. These pollutants have health impacts and contribute to the formation of O_3. The chemistry of air pollution is complex and concentrations in the atmosphere are often interdependent. NO and NO_2 (known collectively as NO_X) are produced through oxidation of nitrogen in the air by combustion at high temperature (including in internal combustion engines). NO and NO_2 react with chemicals in the air to form secondary particulates. They also react with volatile organic compounds (VOC) under the action of sunlight to form ozone. The rate of ozone formation can be limited by NO_X or by VOC concentrations. In the ZMVM the controlling factor is VOCs. At night, in the absence of sunlight, NO breaks down ozone into oxygen and NO_2. .

Table 1.1a. **Selected Mexican National Ambient Air Quality Standards**

	Period	Level	Statistical form of the limit
Ozone	8 hours	70 ppb	Annual maximum moving average for 8 hours
	1 hour	95 ppb	Hourly mean
PM_{10}	24 hours	75 µg/m^3	Daily mean
	Yearly	40 µg/m^3	Annual mean
$PM_{2.5}$	24 hours	45 µg/m^3	Daily mean
	Yearly	12 µg/m^3	Annual mean

Sources: Informe Calidad del Aire 2015; http://www.aire.cdmx.gob.mx/default.php?opc=%27ZaBhnmI=&dc=%27Yw==; http://www.aire.cdmx.gob.mx/descargas/publicaciones/flippingbook/informe_anual_calidad_aire_2015v3/mobile/#p=12,.

Table 1.1b. **Selected US National Ambient Air Quality Standards**

	Period	Level	Statistical form of the limit
Ozone	8 hours	70 ppb	Annual 4th highest daily maximum over 3 years
PM_{10}	24 hours	150 µg/m^3	Not to be exceeded more than once a year over 3 years
$PM_{2.5}$	24 hours	35 µg/m^3	98th percentile averaged over 3 years

Sources: US EPA https://www.epa.gov/criteria-air-pollutants/naaqs-table

Table 1.2. **European Air Quality Standards and WHO Air Quality Guidelines (AQG) (µg/m3)**

	WHO AQG	EU Standard	Averaging period	Days exceedance allowed WHO	EU	EU Air Quality Alert Threshold
O_3	100	120	8 hour daily max		25 average over 3 years	240 (1 hour average)
	50 ppb	*60 ppb*				*120 ppb*
NO_2	40	40	Annual mean			
	200	200	1 hour mean		18	400
PM_{10}	20	40	Annual mean	3	35	
	50	50	Daily mean			50, WHO AQG used *defacto*
$PM_{2.5}$	10	25	Annual mean	3		
	25	-	Daily mean			

Sources: WHO 2006; EU AAQD 2008/50/EC; EU Directive 2002/3/EC relating to ozone in ambient air.

Table 1.3. **Air Quality Index (AQI) Breakpoints in Mexico and the US**

AQI	**Air quality category**		**O_3** (ppb 8-hour)		**O_3** (ppb 1-hour)		**PM_{10}** ($\mu g/m^3$ 24-hour)		**$PM_{2.5}$** ($\mu g/m^3$ 24-hour)	
	MX	US	MX	US	MX	US	MX	US	MX	US
0 – 50	**Buena**	**Good**		0 54	0 70		0 40	0 54	0 12	0 12
51 – 100	**Regular**	**Moderate**		55 70	71 95		41 75	55 154	12.1 45	12.1 35.4
101 – 150	**Mala**	**Unhealthy Sensitive Groups**		71 85	96 154	125 164	76 214	155 254	45.1 97.4	35.5 55.4
151 – 200	**Muy Mala**	**Unhealthy**		86 105	155 204	165 204	215 354	255 354	97.5 150.4	55.5 150.4
201 – 300	**Extrema-damente Mala**	**Very Unhealthy**		106 200	205 404	205 404	355 424	355 424	150.5 250.4	150.5 250.4
301 – 400		**Hazardous**			405 504	405 504	425 504	425 504	250.5 350.4	250.5 350.4
401 – 500					505 604	505 604	505 604	505 604	350.5 500.4	350.5 500.4

Sources: SEDEMA; US Electronic Code of Federal Regulations, Part 58, Ambient Air Quality Surveillance.

Box 1.2. **UK Pollution Alerts**

Air pollution Alerts are issued when any of the following thresholds in EU Directive 2008/50/EC are exceeded:

Ozone Information Notice	180 $\mu g/m^3$ for 1 hour
Ozone Alert	240 $\mu g/m^3$ for 1 hour
Sulphur Dioxide Alert Nitrogen Dioxide Alert	500 $\mu g/m^3$ for 3 consecutive hours over 100km^2 area 400 $\mu g/m^3$ for 3 consecutive hours over 100km^2 area

Source: UK Department for Environment, Food and Rural Affairs, https://uk-air.defra.gov.uk/latest/alerts

The likely development of emissions and air quality in Mexico has been modelled by the Institute for International Council for Clean Transportation (ICCT). Scenarios with and without updating of fuel quality standards and emissions regulations for new light and heavy-duty vehicles to current US standards were prepared. The results are summarized in the following tables and figures and show that without updating of the standards, emissions of particulate matter and VOCs will grow strongly. NO_X emissions will fall at first as new vehicles meeting the current regulations enter the fleet but this effect is then outstripped by growth in the population and the number of vehicles on the road. The strong increase in particulate emissions in the baseline scenario reflects the importance of sulphur in fuel in producing particulates.

Box 1.3. **Health effects of high air pollutant concentrations**

PM — The size of particles is directly linked to their potential for causing health problems. Small particles less than 10 micrometres in diameter pose the greatest problems, because they can get deep into the lungs and some get into the bloodstream. Exposure to such particles can affect both lungs and heart. Particle pollution exposure is linked to a variety of problems, including:

- Premature death in people with heart or lung disease.
- Nonfatal heart attacks.
- Irregular heartbeat.
- Aggravated asthma.
- Decreased lung function.
- Increased respiratory symptoms; irritation of the airways, coughing or difficulty breathing.

People with heart or lung diseases, children, and older adults are the most likely to be affected by particle pollution exposure.

Ultrafine particles — Particulates from vehicle exhaust are a known health risk, which decrease life expectancy and quality of life, although the toxicity mechanisms of the particulate cocktail are still under investigation. The most damaging emissions of all are ultrafine particulates (smaller than 100 nanometres), with metals and other toxic substances attached to their surfaces. These are much smaller even than $PM_{2.5}$, and must be measured by number of particles not by mass as they weigh so little. The carbon particles produced by combustion are in themselves relatively harmless but the toxic chemicals they carry into the cells cause inflammation and damage to cells, resulting in a range of diseases including heart and respiratory diseases and cancers. Gasoline direct injection engines can produce as many ultrafine particles as diesel engines.

NO_2 — Breathing air with a high concentration of NO_2 can irritate airways in the respiratory system. Exposure over short periods can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty breathing), hospital admissions and visits to emergency rooms. Longer exposures to elevated concentrations of NO_2 may contribute to the development of asthma and potentially increase susceptibility to respiratory infections. People with asthma, as well as children and the elderly are generally at greater risk for the health effects of NO_2.

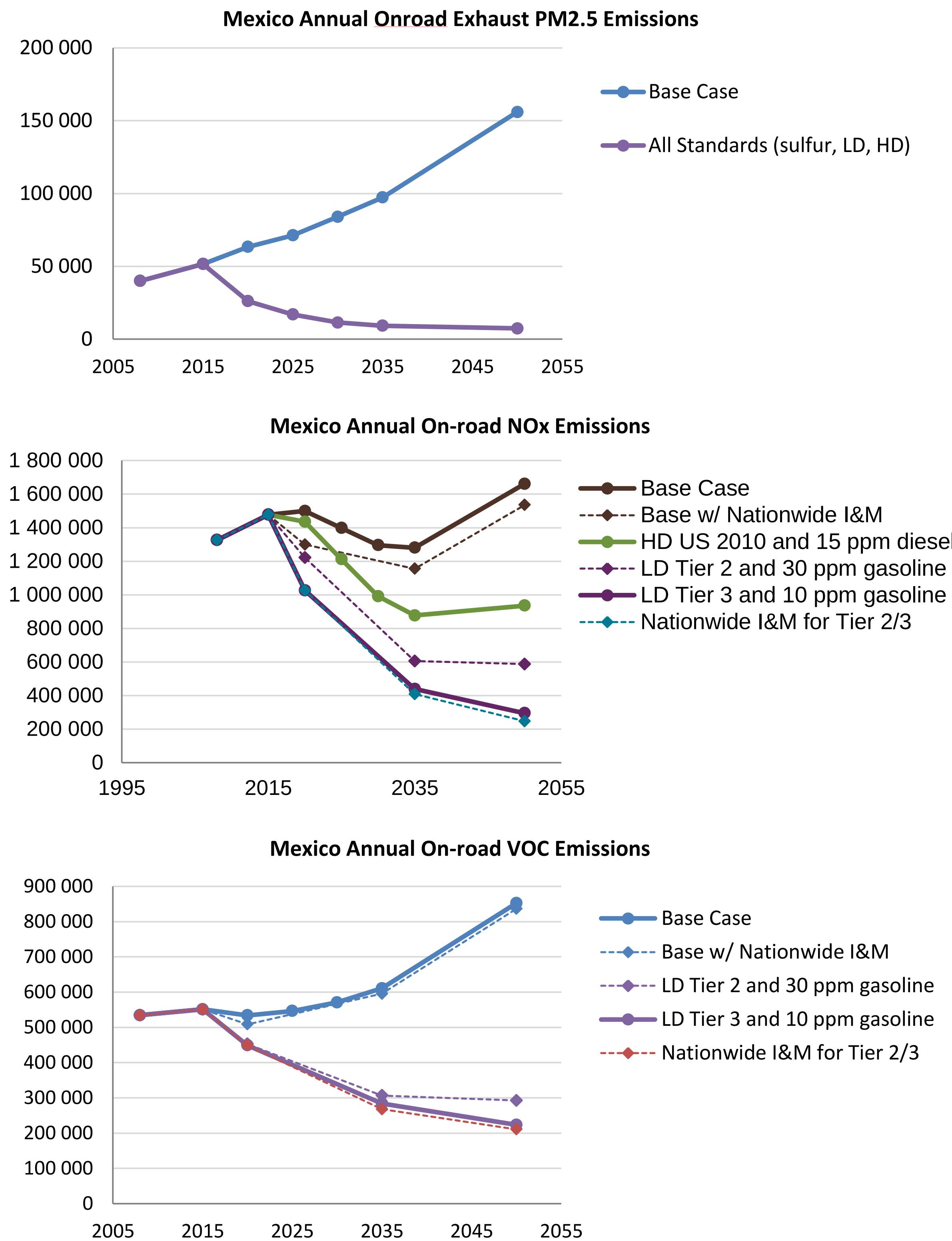
O_3 — Ozone can cause the muscles in the airways to constrict (as the body responds to exposure by trying to prevent absorption into the blood), trapping air in the alveoli. This leads to wheezing and shortness of breath and reduced levels of oxygen in the blood. Ozone can:

- Make it more difficult to breathe deeply and vigorously.
- Cause shortness of breath, and pain when taking a deep breath.
- Cause coughing and sore or scratchy throat.
- Inflame and damage the airways.
- Aggravate lung diseases such as asthma, emphysema, and chronic bronchitis.
- Increase the frequency of asthma attacks.
- Make the lungs more susceptible to infection.
- Cause chronic obstructive pulmonary disease.

These effects have been found in healthy people, but can be more serious in people with lung diseases such as asthma. Long-term exposure to ozone is linked to aggravation of asthma, and is likely to be one of many causes of asthma development. Long-term exposures to higher concentrations of ozone may also be linked to permanent lung damage, such as abnormal lung development in children.

Source: US EPA, https://www.epa.gov/no2-pollution/basic-information-about-no2#Effects (except for ultrafine particules).

Figure 1.1. **Scenarios for emissions from light and heavy-duty vehicles (tonnes)**



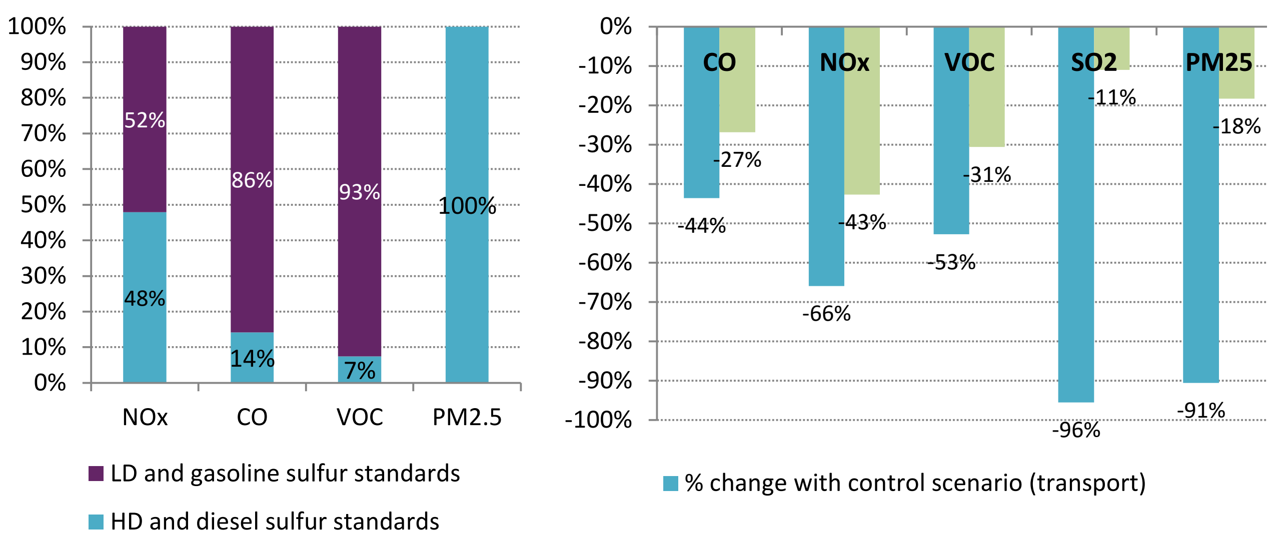
Source: ICCT, workshop presentation by Kate Blumberg.

Table 1.4. **Fuel quality and vehicle emission standards scenarios for Mexico**

Regulation	Fuels/Vehicles	Base scenario (2016 standards)	Control scenario	
Fuel standards	Gasoline	Metro areas: 30 ppm Rest: 85% 300 ppm; 15% 30 ppm	2016 2017-2019 2020+	150 ppm 30 ppm 10 ppm
	Diesel	Metro areas: 15 ppm Rest: 500 ppm	2016-2017 2018-2019 2020+	500 ppm 15 ppm 10 ppm
Vehicle emission standards	Light-duty	PM: US Tier 1 NOx: US Tier 2 bin 7 Phase-in complete after 2013	2018-2020 2021-2024 2025+	Tier 2 Tier 3 phase-in Tier 3
	Heavy-duty	EPA 2004	EPA 2010	

Source: ICCT, workshop presentation by Kate Blumberg, 2017.

Figure 1.2. **Contribution of standards to emissions reductions in 2035**



Source: ICCT, workshop presentation by Kate Blumberg..

Table 1.5. **Difference in air quality between scenario with updated standards and baseline, 2035**

Air quality indicator (population-weighted)	Nationwide	Mexico City
Annual mean $PM_{2.5}$	-17.6%	-19.5%
8-hour maximum ozone	-8.1%	-4.9%
1-hour maximum ozone (annual mean)	-9.5%	-6.3%
1-hour maximum ozone (spring mean)	-11.8%	-13.7%

Source: ICCT, workshop presentation by Kate Blumberg.

Controlling emissions in Mexico's real-world urban driving conditions

The factors that drive excess emissions from vehicles in the real-world traffic conditions of the city are critical to determining priorities among the potential measures to mitigate air pollution. Recent research has greatly improved the understanding both of emissions in the real world and the damage done to health (see: Chapter 3; ECMT, 2006).

In Mexico City traffic is dense and frequently heavily congested with low average speeds and stop-go conditions. Emissions control technologies must be effective in these conditions if they are to effectively cut emissions in the city.

New vehicles sold in Mexico comply with either US or EU emission standards, both are valid and manufacturers can chose which equivalent standard to follow. For cars and heavy trucks both regimes are used in practice but most buses are manufactured in compliance with the European standards.

Heavy-duty vehicle emissions standards adapted to congested roads

Until the most recent generation of heavy vehicles, compliant with Euro VI / EPA 2010[2] standards, nitrogen oxide (NO_X) emission control systems performed poorly in urban conditions. In particular, the test regime in the EU, which focused on a very narrow range of engine performance, drove adoption of technology that fails to remove NO_X until engines reach temperatures much higher than typical in urban traffic. In addition, the standards for heavy vehicles in both Europe and the US focus on conditions of relatively high engine loads and speed. Powerful modern truck engines almost never reach these loads in city traffic. In consequence the engines developed respect emissions limits under open highway driving conditions, where the latest trucks produce less pollution than most diesel cars,[3] but performed poorly outside of these conditions until effective in-service compliance rules were incorporated. In Europe, this was with the 2013, Euro VI generation of standards. These standards also adopted a particulate number limit for the first time, important in providing the necessary incentive to control ultrafine particulate emissions.

Until off-cycle on-road testing was incorporated, successive emissions standards saw little or no improvement in cutting NOx emissions in urban driving conditions. The first results of real-world testing of Euro VI vehicles are promising, although more research will be required to establish conclusively that this generation of vehicle performs reliably under prolonged urban-only use. Specialised vehicles such as garbage trucks will require particular attention due to their atypical drive cycles. Depollution systems can also be tampered with in use to increase power or to avoid the need for refills with NO_X-control reagent (urea solution marketed as AdBlue). Regular inspection is required to ensure this does not happen.

US regulations imposed stronger on-board diagnostic (OBD) requirements than under Euro V standards so suffered much less of a NO_X control performance gap, but even under the new emissions control test regimes, both the EU and US truck emissions control technologies work most effectively at prolonged constant speeds of 50 to 90 km/h, i.e. open highway driving. Clearly it is not possible to ensure trucks can always drive at these speeds in urban environments. Additionally, apart from on urban freeways, speeds must be limited to 50 km/h or less for road safety imperatives.

Early adoption of Euro VI standards for buses and trucks

Current federal emissions standards in Mexico for new trucks and buses specify Euro IV regulations. Promoting Euro V vehicles would achieve little gain. The standards and procedures adopted for Euro VI, on the other hand, have achieved a ten-fold improvement, largely because of the adoption of new in-service compliance requirements. Mexico City has rightly adopted these standards under its voluntary inspection and maintenance (I&M) scheme, which exempts trucks from restrictions on circulation when pollution alert countermeasures apply. The proposed adoption of Euro VI standards under federal regulations for new vehicles in 2020 should be agreed without further delay and ideally brought forward. A potential two-year transition phase with Euro V standards, currently under consideration, would clearly be counter-productive; ICCT estimates that it would result in one million tonnes excess NO_X emissions a year. The voluntary I&M scheme for heavy vehicles clearly demonstrates that there is no obstacle to using Euro VI trucks in the Mexican market today.

Ultrafine particles from gasoline engines

Unlike diesel emissions controls (for both heavy and light-duty vehicles), the three-way catalytic converters used to control emissions on gasoline cars have shown very good correlation between test and real world performance, with successive improvements in control with each generation of emission standard. However, emissions of particulates were only measured in terms of mass not number until the latest, 2015 Euro 6 light-duty vehicle standards (EUR-LEX, 2012).[4] The change was in response to the spread of gasoline direct injection (GDI) engines, which if not appropriately controlled emit ultrafine particulates, albeit on a much smaller scale than poorly maintained vehicles that burn lubricating oil. GDI cars are spreading rapidly in Latin America, including in Mexico, and controlling them with a particle number limit is important.

Evaporation of gasoline

In relation to emissions of volatile organic compounds (VOCs), the US EPA 2010 Tier 3 light-duty vehicle regulations have stricter, more effective controls than European standards for controlling fugitive hydrocarbon emissions – evaporative losses from the engine, petrol tank and during refuelling. The seals and vapour traps used to achieve the limits are not advanced technology and do not add significant cost to vehicles. Controlling these emissions is particularly important in Mexico as high temperatures and the high altitude mean such losses are large when uncontrolled and are an important source of ozone precursor emissions. Moreover VOCs appear to be the limiting factor in the formation of ozone in the Valle de Mexico.

Cutting VOC and ultrafine particulate emissions in the ZMVM

Ideally Mexico should adopt a combination of the latest European and US light-duty emissions standards to address emissions of both ultrafine particles and volatile organic compounds. Following the usual approach and allowing manufacturers to meet either standard to replace the current Euro 4 standards as quickly as possible is indicated. In the immediate term Mexico City could introduce incentives in its inspection and maintenance and No-driving day (HNC) systems to promote a shift to Tier 3 compliant vehicles, to contribute to reducing excess ozone pollution episodes.

Controlling off-road vehicle emissions and the use of advanced filters

Controlling emissions from off-road vehicles is an important part of air quality improvement in cities and should become part of mitigation strategies in Mexico. These emissions are regulated under national emissions standards in Europe and the US.[5] Non-road mobile machinery emissions have been regulated in the European Union since 1997. The latest regulations (2016/1628) apply from 1 January 2017 and should be the reference for development of a standard in Mexico.

Retrofit and local proving of emission control technologies

Mexico City has run a pilot diesel particulate filter (DPF) retrofit programme for buses since 2015. This follows successful real world testing of retrofits in 2005 by SEDEMA with CTS-Embarq Mexico, US EPA and US AID, that found them to be effective in reducing particle numbers as well as the mass of particulate emissions. Given the challenges of urban driving conditions for filter regeneration, continued monitoring will be essential to the credibility of the program as it is expanded. Severe problems with DPF retrofit programs have been encountered elsewhere, for example in the Netherlands, where filters have suffered rapid clogging, sometimes resulting in fires. A specific maintenance and inspection regime is needed for large scale retrofit programs.

For selective catalytic reduction (SCR) NO_X treatment systems on heavy-duty vehicles, in-use testing will also strengthen the credibility of any incentives to introduce vehicles that use this technology (Euro V and Euro VI trucks and buses). As noted, early testing of Euro VI trucks in urban conditions shows a ten-fold improvement over previous vehicles but testing on a broad range of vehicles including buses and garbage trucks is indicated given the disappointing results of SCR technology on older vehicles in urban conditions. At the workshop, transport for London emphasised the importance of the research and testing in local conditions that it commissions to support development of London's low emissions zones and bus replacement schemes as important to the effectiveness and public acceptance of the measures taken. TfL developed its own test cycle to match conditions in London traffic and its verification program was important to the success of SCRT retrofits on London buses.

Ensuring the quality of retrofitted pollution control equipment is essential. Even some of the three-way catalytic converters available on the after-market are poor quality and perform badly and should not be used in retrofit programs. Certification and inspection of approved systems for retrofit is important together with monitoring of accredited installers of aftermarket emissions control systems. Certification needs to include durability regulations with a five-year/50 000 miles (80 000 km) warranty. For particle filters certification should ideally cover the efficiency in terms of reducing particle numbers as well as the mass of emissions.

Fuel quality

Ultra low sulphur gasoline and diesel

Reducing the sulphur content of gasoline and diesel would have immediate benefits for air quality in the ZMVM. Reducing sulphur in gasoline to 10 ppm would improve the performance of the catalytic converters on every car on the road. Ultra low sulphur diesel at 15 ppm is ideal for the latest particulate filters and NO_X control systems. This fuel is available in Mexico City, although not everywhere in the country, and there are diesel particulate filter systems that work effectively at much higher sulphur levels (only systems using precious metal coatings are sensitive to sulphur).

The availability of low sulphur fuel in Mexico City is not an obstacle to incentivising the latest emissions control technologies but promotion of low sulphur fuel, for example through differentiated taxation, would have significant immediate benefit. Clamping down on illegal sales of non-standard fuels through unregistered distribution channels would also have pollution benefits and protect vehicle owners from damage to their engines.

Alternative fuels and drivetrains

Electric vehicles produce no tailpipe emissions and are a potentially valuable part of emissions mitigation strategies. The cost of unsubsidised vehicles makes electric passenger cars a marginal part of the market in Mexico to date. The city has plans for an electric highway on one of its southern arterial roads, with investment in electric buses. There are also several existing electric trolley bus routes – a relatively low-cost alternative that might be expanded. Transport for London now requires all new double-decker buses to be hybrid diesel-electric and all single deck buses to be electric. It plans to convert all taxis to plug-in petrol-electric hybrid engines. Mexico City began a pilot project to support the introduction of electric taxis in 2012 which continues to expand.

Natural gas conversions have been used successfully in cities including Delhi to cut emissions of particulates from buses, microbuses and motorised rickshaws as engine-out emissions are very low. They have made a particularly useful contribution to mitigation and sustainability strategies in Gothenburg in Sweden where buses run on methane recovered from digesting solid waste from water treatment plants. There are some issues associated with natural gas vehicles. Leakage in the transport and fuelling of natural gas adds to VOC and greenhouse gas emissions. CNG motors have lower torque than diesel or gasoline engines and the storage of gas on the roof of buses changes the handling characteristics of the vehicles. NO_X emissions can be high if poorly controlled. CNG vehicles could be part of mitigation strategies in Mexico if high standards of pipeline transport and refuelling are met.

Liquefied petroleum gas (LPG) presents similar characteristics to natural gas in combustion. However, LPG distribution is restricted under current ozone alert response measures in the ZMVM and encouraging its use for vehicles might therefore be problematic. Its main advantage is cost, with market prices usually somewhat below gasoline or diesel.

Policies to promote the use of electricity for transport in the city at reasonable cost, i.e. trolley buses and the metro and small scale market development pilots, are the most pertinent of the options for alternative fuels and drivetrains.

Incentives for early adoption of cleaner vehicles

In anticipating future federal standards to promote cleaner vehicles at the local level, Mexico City is following good practice elsewhere. European Union emissions regulations allow member states to use tax incentives (differentiated registration and road use taxes) to accelerate introduction of vehicles meeting new standards ahead of the regulatory deadlines. A number of countries have made use of this facility. In all of the European countries where electronic road pricing has been introduced for heavy vehicles rates have been differentiated according to the Euro emissions class of the vehicle. Germany used road pricing discounts in 2005 to stimulate early development of the market for Euro V trucks. Greater use could be made of this approach in Mexico, for example with incorporation of Euro VI standards in the eco-zones under development in a number of cities in the CAMe region In addition, vehicle categories “00”and “0”, assigned according to the I&M system, could also be differentiated, reserving the “00”category for Tier 3/Euro 6 light-duty vehicles (see next section).

Most European countries have differentiated vehicle taxation on environmental grounds following an EU policy paper on taxation that promoted differentiation on the basis of CO_2 emissions (EU, 2005). Taxes on registration and ownership of vehicles and annual circulation taxes have been differentiated on the basis of emissions in 20 member states (ACEA, 2016), replacing flat rate charges and charges taxes based on the value of cars (some use a combination of factors). This has had a powerful effect on the market for new cars. Taxation is most strongly differentiated in France, Denmark and the Netherlands and the average fuel economy for new cars is lowest in these countries. Differentiation of vehicle taxes in relation to air pollutant emissions would have a similar market steering effect.

In Mexico, the *tenencia* is a vehicle ownership tax, devolved to the Federal States since 2012. Some States have abolished the tax but those that retain it set rates in relation to the value of the car with exemption in some cases below a minimum threshold. The three States of the ZMVM levy the tax but set different thresholds, USD 18 000 in Mexico City, USD 26 300 in the State of Mexico and USD 41 350 in Hidalgo (OECD, 2015). In the CAMe region Tlaxcala has a threshold of USD 26 300, Puebla and Morelos no longer levy the tax. These differences lead many households in Mexico City to register vehicles in other States. Restructuring the tax in the States levying it to provide incentives for Tier 3 / Euro 6 vehicles, with a taper rather than a cut-off threshold to differentiate according to value, would provide a valuable stimulus to the market for clean vehicles. Weaker incentives might be included for Tier 2 / Euro 4 cars.

Inspection and maintenance

A stringent emissions control inspection and maintenance (I&M) system has been developed for the ZMVM, requiring inspection twice a year. In 2014, with support from the Environmental Commission for the Megalopolis (CAMe), the six States of the megalopolis agreed to harmonise all I&M programmes with the system in the ZMVM. Harmonising the programmes has long been an objective because in addition to the benefits to the population in each of these states of bringing all inspection procedures and emission standards up to the level of the ZMVM, a large number of vehicles from the area travel through the ZMVM in a daily basis. Moreover there was a strong incentive to register vehicles outside Mexico City in States with less stringent I&M procedures.

In June 2016, the National Ministry of Environment (SEMARNAT) issued an emergency standard (NOM – EM-167-SEMARNAT-2016) that applies in all CAMe States. This emergency standard will be replaced by a permanent standard in July 2017. The new standard established OBD checks as part of the mandatory vehicle emissions testing and inspection programme. It also revised the limits for tailpipe testing and introduced testing with remote sensing devices to identify high-emitters on the street.

Inspection based on interrogation of the cars' OBD system allows rapid processing and, in many cases, identification of the likely cause of any excess emissions. It also records the functioning of emissions control systems in use over time and guards against interference with engine controls to change the performance characteristics of the vehicle specially to pass the emissions test. OBD testing detects four and a half times as many defects as a standard tailpipe emissions test according to data from California's I&M system. However, until all vehicles in Mexico have a homologated and certified OBD system, reliance on only OBD testing for determining compliance on emission levels is not possible. Based on Mexico City´s experience since July 2016, some vehicles with high measured tail-pipe emissions would have passed inspection if only OBD checks had been required. Therefore OBD checks combined with tailpipe exhaust emission tests should be used for vehicle certification in Mexico City and this system should be extended throughout the CAMe States as planned. Measures to thwart OBD system manipulation should be considered to prevent illegal falsification of results.

In response to recent challenges in court to the legality of using OBD checks in addition to tailpipe sampling, the CAMe authorities should prepare a report on the importance of OBD to achieving the environmental objectives of the law on the obligatory vehicle maintenance system. This should be prepared to standards sufficient for judges in the constitutional courts to accept the necessity of OBD testing.

The requirement for I&M centres to use OBD checks has delayed the process of harmonising the inspection system across the CAMe States (in the meantime vehicles registered in States where the technology is not available can go through voluntary I&M in Mexico City and State of Mexico).

Nonetheless, completing the transition along with the introduction of the more stringent emission standards specified by the new regulation will reduce pollution.

Notwithstanding this improvement, the omission of motorcycles from the system is an important flaw that needs to be addressed. While these vehicles still constitute a small share of the fleet, their numbers are rapidly increasing and a significant share have two-stroke engines and thus emit high levels of emissions. Affordable electric motorcycles are rapidly replacing conventional motorcycles in Chinese cities and could be incentivised under the I&M system.

Fraud and enforcement have been a persistent problem in I&M systems wordwide. Although Mexico City has implemented its own Centralized Vehicular Inspection Information System (SIVEV) and established a Remote Inspection and Surveillance Center (CIVAR), enforcement remains a challenge. To eliminate fraud, the system could introduce some of the procedures used in California. Tests are carried out in licenced concessions throughout the State but the data from the tests is transmitted electronically via the internet to a central analytical station in Sacramento City which issues the test result. This effectively guards against many kinds of fraud in the local garages that run the tests. Licenced concessions are also subject to periodic audit and undercover operations to inspect unmarked control vehicles are mounted as an additional check to prevent fraud.

In California, OBD testing is backed by cross-checks that strip down engines that pass tailpipe emissions tests and fail OBD tests, and vice-versa, to understand the causes of failure. A team of around 30 people work on ensuring and improving the quality of the regime. In the European Union tailpipe emissions gas sampling remains the principle test method because of the unfolding emissions defeat device scandal surrounding diesel cars. Both OBD and tailpipe testing are needed for a reliable inspection considering the range of vehicle ages and the standards/OBD requirements they are certified to. California is also switching to OBD based testing for heavy-duty vehicles equipped with these systems.

In addition to harmonising testing procedures and standards, the I&M system would benefit from a joint agreement of CAMe States to harmonise enforcement procedures. Significant shares of non-compliant vehicles still exist in the megalopolis zone. For this to change it is important that all States within the Megalopolis make effective the mandatory character of the I&M programme by imposing a sanction in the case of non-compliance (in the States of Morelos, Hidalgo, Puebla and Tlaxcala this is not the case). In addition, an agreement for all six States of the megalopolis to enforce payment of fines imposed on vehicles registered in their State regardless of where in the region the vehicle was stopped and fined, e.g. for breaching *Hoy no circula* restrictions (see following section), would make a major contribution to improved emissions control.

A majority of jurisdictions in OECD countries require heavy and light-duty vehicles to undergo periodic motor vehicle inspections for safety and roadworthiness although in some inspections are required only on transfer of ownership. In most federal countries, including the US, Canada and Australia, the type of inspection regime is the responsibility of State jurisdictions. In the US, 17 States require periodic safety inspection. In Australia all States require roadworthiness testing, either periodic inspection or testing on transfer of the vehicle. Japan requires cars to undergo safety and roadworthiness testing after three years and then every two years. In the European Union, Directive 96/96/EC requires all member states to carry out periodic safety and emission inspections for all motor vehicles and sets minimum standards for inspection of private and commercial vehicles. Private cars and commercial vehicles up to 3.5 t must be inspected after 4 years at the latest and then every two years. Heavy-duty vehicles and taxis must be tested annually for safety and roadworthiness. Around half of the EU member states begin testing at three years, with some from two years, and many make testing annual from 10 years onwards.[6]

Roadworthiness and safety testing have benefits also for the environment as worn mechanical parts such as brakes or tyres can result in excess particulate matter emissions. It is estimated that exhaust and non-exhaust traffic-related sources contribute almost equally to total traffic related PM_{10} emissions (EEA 2016a; JRC 2014). The composition of the emitted particles depends on the materials used in the manufacture of brake linings, tyres and asphalt. Heavy metals, organic compounds, sulphur, hydrocarbons and other toxic materials are emitted during the wear processes

Box 1.4 **Car ownership restrictions in Asia**

In China a number of cities restrict vehicle ownership rather than use. Shanghai was the first city to introduce auctions for the right to own a car, in 1994. The result is that car numbers per head and per dollar of GDP are half those in Beijing. The value of a car licence plate is currently USD 12 500 in Shanghai. With congestion and air pollution increasingly serious problems, Beijing introduced its own lottery-based restrictions on car ownership in 2010. Since then six other cities have introduced combinations of auctions and lotteries. Elsewhere in Asia, Singapore has the most complete system of instruments to manage car ownership and use. It employs a licence plate auction system that roughly doubles the cost of owning a car. Land-use and public transport policies are tightly integrated and dynamic road charging is used to control access to the centre and fine tune the speed of traffic on arterial roads (ITF, 2010).

Restrictions on the use of vehicles

An increasing number of cities around the world restrict access for vehicles to the city centre or restrict access to over a larger area to the cleanest or most recent vehicles. This creates incentives to purchase cleaner vehicles. In some cases these incentives are designed to anticipate national emission standards.

Like Mexico City, a number of authorities in Europe also use traffic restrictions as pollution control measures during peak pollution episodes. France introduced windscreen stickers to classify vehicles by emissions characteristics under its new *Crit'air* system in 2016, using it to limit vehicle circulation during pollution episodes for the first time on 23 January 2017. The standards apply nationally and the mayors of cities with an air pollution problem are able to make use of it as required by local mitigation programmes. The system is differentiated similarly to Mexico's *Hoy no circula* (HNC), although based simply on the emissions regulations applicable to each vehicle rather than the results of vehicle testing. The scheme entered force in January 2017, replacing an undifferentiated system of odd-even number plate driving restrictions on alternate days during pollution episodes.

The vehicle classification system is set out in Table 1.6, largely corresponding to age but differentiated by the fuel used by the vehicle. Older and dirtier vehicles are prohibited from driving throughout pollution episodes. The more severe the pollution the more categories of vehicle are restricted. All electric vehicles are classified green and exempt restriction. All plug-in hybrids and vehicles fuelled with compressed natural gas are rated 1 and exempt restrictions together with Euro 5 gasoline light-duty vehicles, Euro VI heavy-duty diesel vehicles and Euro 4 motorcycles. The countermeasures applied on 23 January 2017 banned the circulation of category 5 vehicles (Euro 2 light-duty diesel vehicles and Euro III heavy-duty vehicles) along with all older, unclassified vehicles.

Table 1.6. **France's Crit'air vehicle classification system, 2016**

Classification des véhicules en application des articles L. 318-1 et R. 318-2 du code de la route

Classe	2 ROUES, TRICYCLES ET QUADRICYCLES À MOTEUR	VOITURES	VÉHICULES UTILITAIRES LÉGERS	POIDS LOURDS, AUTOBUS ET AUTOCAR
CRIT'Air (vert)	Véhicules électriques et hydrogène			
CRIT'Air 1	Véhicules gaz Véhicules hybrides rechargeables			

Classe	DATE DE PREMIÈRE IMMATRICULATION ou NORME EURO						
	2 ROUES, TRICYCLES ET QUADRICYCLES À MOTEUR	VOITURES		VÉHICULES UTILITAIRES LÉGERS		POIDS LOURDS, AUTOBUS ET AUTOCAR	
		Diesel	Essence	Diesel	Essence	Diesel	Essence
CRIT'Air 1	EURO 4 À partir du : 1er janvier 2017 pour les motocycles 1er janvier 2018 pour les cyclomoteurs	-	EURO 5 et 6 À partir du 1er janvier 2011	-	EURO 5 et 6 À partir du 1er janvier 2011	-	EURO VI À partir du 1er janvier 2014
CRIT'Air 2	EURO 3 du 1er janvier 2007 au : 31 décembre 2016 pour les motocycles 31 décembre 2017 pour les cyclomoteurs	EURO 5 et 6 À partir du 1er janvier 2011	EURO 4 du 1er janvier 2006 au 31 décembre 2010	EURO 5 et 6 À partir du 1er janvier 2011	EURO 4 du 1er janvier 2006 au 31 décembre 2010	EURO VI À partir du 1er janvier 2014	EURO V du 1er octobre 2009 au 31 décembre 2013
CRIT'Air 3	EURO 2 du 1er juillet 2004 au 31 décembre 2006	EURO 4 du 1er janvier 2006 au 31 décembre 2010	EURO 2 et 3 du 1er janvier 1997 au 31 décembre 2005	EURO 4 du 1er janvier 2006 au 31 décembre 2010	EURO 2 et 3 du 1er octobre 1997 au 31 décembre 2005	EURO V du 1er octobre 2009 au 31 décembre 2013	EURO III et IV du 1er octobre 2001 au 30 septembre 2009
CRIT'Air 4	Pas de norme tout type du 1er juin 2000 au 30 juin 2004	EURO 3 du 1er janvier 2001 au 31 décembre 2005	-	EURO 3 du 1er janvier 2001 au 31 décembre 2005	-	EURO IV du 1er octobre 2006 au 30 septembre 2009	-
CRIT'Air 5	-	EURO 2 du 1er janvier 1997 au 31 décembre 2000	-	EURO 2 du 1er octobre 1997 au 31 décembre 2000	-	EURO III du 1er octobre 2001 au 30 septembre 2006	-
Non classés	Pas de norme tout type Jusqu'au 31 mai 2000	EURO 1 et avant Jusqu'au 31 décembre 1996	EURO 1 et avant Jusqu'au 31 décembre 1996	EURO 1 et avant Jusqu'au 30 septembre 1997	EURO 1 et avant Jusqu'au 30 septembre 1997	EURO I, II et avant Jusqu'au 30 septembre 2001	EURO I, II et avant Jusqu'au 30 septembre 2001

Source: Mairie de Paris.

Enhancing Mexico City's Hoy No Circula (No-driving Day) programme in the short term

The ZMVM's *Hoy No Circula* (HNC) vehicle restriction system provides incentives for fleet modernisation by exempting cleaner vehicles from restrictions and placing the most extensive restrictions on the most polluting vehicles. This is a significant improvement on most other restriction systems based on licence plate number, which make no differentiation between vehicle emission characteristics. Driving restrictions are applied on a regular basis, not just during high pollution episodes. The regular restrictions apply one day a week (the day depends on the last digit of the number plate) and two or all Saturdays, depending on the tested emission characteristics of the vehicle (Table 1.7). During peak pollution episodes additional vehicle use restrictions are implemented as part of the environmental alert programme (PCAA). Between April and July 2016, restrictions on vehicle use during alerts were extended to all light-duty vehicles regardless of emissions class (overriding exemptions for 00 and 0 classes). Additional restrictions were also applied during the alert to fuel distribution centres, carburation centres and freight transport. In the case of the latter, this has meant that driving restrictions based on number plates, and regardless of vehicle emission classification, are applied to all freight vehicles traveling through the ZMVM. These additional measures were agreed as a result of co-ordination ofby the States and Federal Governments through the CAMe.

The HNC classifies vehicles according to emissions control equipment and the results of I&M tests. Vehicles are identified using the windscreen stickers issued by the I&M programme. Electric and hybrid vehicles obtain a windscreen sticker that entitles them to be exempt from all driving restrictions. Vehicles classified “00” and “0” are also exempt from regular restrictions. Normally they are also exempt from restrictions during pollution alerts but the special measures applied by the CAMe from April to July 2016 extended restrictions to these vehicles.

Table 1.7. **No-Driving Day scheme restrictions on vehicle use**

		Restrictions on vehicle use for certified inspection categories 1 and 2 (00 and 0 types exempt)		
Windscreen sticker colour	Last digit on number plate	Weekdays	Saturdays 05:00-22:00	
			1	**2**
Yellow	5 & 6	Monday	Odd plates 1st and 3rd Saturday of the month Even plates 2nd and 4th Saturday of the month	All vehicles every Saturday
Pink	7 & 8	Tuesday		
Red	3 & 4	Wednesday		
Green	1 & 2	Thursday		
Blue	9 & 0	Friday		
Uncertified vehicles				
Every day			05:00-11:00	Every Saturday 05:00-22:00
Plus one day a week			05:00-22:00	

Source: SEDEMA.

The “00” classification is given to new light-duty vehicles (complying with Euro 4 / EPA Tier2 standards or better) and heavy-duty diesels that comply with Euro VI / EPA 2010 standards. “0”classification can be attained by light-duty vehicles with a three-way catalytic converter and a second generation OBD system, meeting emission standards equivalent to Euro 3 / EPA Tier 1 (corresponding to 2006 models onwards). Cars of this type can also be given a “1” sticker according to I&M emissions test results. “0”stickers are awarded to heavy-duty diesels that meet Euro IV / EPA 2004 (2008 models onwards) and present no faults on OBD testing. Restrictions apply to vehicles classified “1” and “2” as described in Table 1.7. Details of the emissions testing requirements are outlined in Chapter 2; see Table 2.5 for a summary of current requirements for certification of gasoline, diesel, natural gas, hybrid and electric vehicles.

Programmes that link traffic restrictions to environmental performance need continuous updating as new technologies become available. New emission limits for the ZMVM were introduced by NOM – EM-167-SEMARNAT-2016 as one of the responses by CAMe to ozone alerts. These were incorporated in the I&M testing program, notably introducing the OBD test requirement for heavy and light-duty vehicles to obtain “0” rating, thus resulting in stricter requirements for exemption from traffic restrictions. Incentives to stimulate development of a market for Euro 6 / Tier 3 light-duty vehicles in the ZMVM could be introduced through the system ahead of national standards for all new vehicles through addition of a “000” class or modification of the categories of vehicle eligible for “00” and “0” classes. Restrictions imposed during pollution peaks could then take advantage of this difference, exempting only vehicles with the most advanced technologies, and imposing some restrictions on all other vehicles.

Currently motorcycles are not included in the I&M or HNC systems. This should be rectified, with differentiation between less and more polluting vehicles, with or without testing. As in the case of France, motorcycles can be classified using the same stickers as for other vehicles.

Enforcement

The effectiveness of measures to restrict the use of vehicles, both on a regular basis as well as during smog episodes, depends on the extent to which they are respected. The penalties for contravening the restrictions in Mexico City can be severe (including confiscation of vehicles) and the restrictions are enforced by the police with fines. One weakness is that fines levied by the police force in Mexico City on vehicles registered in other States are not pursued if unpaid. An agreement on reciprocal processing of fines between the States co-operating in the Regional Environment Commission (CAMe) would be useful in closing this loophole.

Automatic number plate recognition (ANPR) systems are used to enforce restrictions in many cities operating low emissions zones, congestion charges and tolls for the use of infrastructure. These could be applied to the no-driving day and pollution alert restrictions in Mexico City and to future schemes. ANPR is suited to controlling access to relatively small areas because of the cost of monitoring a large number of access points on an extensive road network but can also usefully be deployed less systematically to monitor some of the main trunk roads used by large numbers of vehicles. ANPR is already in use in Mexico City to enforce speed limits on sensitive parts of the urban freeway network.

During the discussions at the workshop, Transport for London stressed the importance of monitoring the compliance of restrictions on vehicle use and incentives to use cleaner vehicles as one of the keys to acceptance of such mitigation measures.

Use of revenues

Revenues from charges for I&M services, from fines for contravening restrictions on vehicle use and from charges to access eco-zones or congestion charging zones can be used to fund flanking measures. This can enhance acceptance of emissions control policies. In California, for example, an USD 8 certification fee is levied on top of the charge for I&M testing. This is used in part to fund a program that assists poor households with up to a USD 500 grant towards repair or up to USD 1 500 for replacement of vehicles that fail emissions testing. In London around half of the revenues from the congestion charge to enter the central part of the City are absorbed by the cost of implementing the system with ANPR. The remaining revenues are invested in the public transport system, particularly in enhancing the bus network. In Mexico City there is no earmarking of revenues from enforcement of restrictions on the use of vehicles today, but this might be considered either to fund better enforcement or to invest in public transport or cleaner vehicles. Some of these revenues could also be directed to reinforcing the technical capacity of the CAMe. Currently, CAMe’s budget is composed of funds assigned by the Federal Government plus a fund composed of resources allocated by member States (equivalent to MXN 5 (Mexican pesos) for every vehicle controlled by I&M programmes) (OECD, 2015). Given that the institution needs to develop expertise on multiple transport and non-transport related environmental issues, channelling some of the charges levied from car regulation to training and to expanding the staff of CAMe could significantly strengthen the capacity of the institution to provide the evidence base for decisions taken by the governing body of the institution.[7]

Shifting towards alternative traffic restriction schemes

A range of systems to restrict traffic are used in cities around the world, including low emission zones (LEZs), congestion charging systems and road pricing schemes, with the primary or secondary aim of improving air quality. The effects of these schemes are instructive as the authorities in the ZMVM and the larger CAMe region examine ways to increase the effectiveness of the HNC and consider potential alternative schemes.

Number plate based restriction systems tend to create perverse incentives for households to purchase a second vehicle with a registration number that permits driving on the days the first vehicle is restricted. A second vehicle in the household generally results in higher mileage driven overall and the second vehicle is often an older car with high emissions. Studies of the impacts of the HNC in Mexico City found evidence that this was the case with the HNC when it was introduced, with reductions in congestion and pollution attained in the period immediately after implementation largely off-set in the longer-run (Gallego et al., 2013). The HNC programme saw important adjustments in 2008 when exemptions for cleaner vehicles were introduced, creating incentives to buy new vehicles instead of second vehicles. Later studies demonstrated that, while there is still evidence of an increase in the vehicle fleet due to the programme (of about 3%), the programme had an important effect in accelerating fleet renewal (Centro Mario Molina, 2013). Earlier evaluations show that identifying impacts among different income groups and between times of the day is of relevance (Gallego et al., 2013). Another common way of coping with the restrictions has been to use taxis. Because of over-supply, taxi rides are relatively cheap and there is no shortage of taxis despite being subject to the HNC. Another strategy is to organise rides with other household members or friends. Since such carpooling trips do not necessarily share the same itinerary, in many cases trip length increases (Davis, 2017).Conducting a detailed study to quantify each of these effects and their ultimate result in terms of emissions would provide a solid basis for future reforms of the programme.

Restrictions under LEZs, congestion charging and road pricing schemes are applied uniformly every day, or every week-day. Thus, the purchase of additional vehicles is not a solution for avoiding restrictions. More polluting vehicles are subject to control every day and, in some cases, occasional use of dirtier vehicles is permitted against payment for access rather than according to number plate. This provides stronger incentives to switch to cleaner vehicles or to public transport.

Box 1.5 describes the Integrated Impact Assessment that was carried out by TfL for the Ultra-Low Emission Zone in London. As was the case in London, such evaluations need to consider socio-economic impacts, particularly for vulnerable groups, and a strategy for supporting these groups in coping with such effects should be developed.

A number of small scale LEZs with differing characteristics are under consideration in city centres in the megalopolis. Co-operation through the CAMe could play an important role in generating guidelines and expertise for the design of such schemes and alternatives and complementary measures to the HNC in general. In the case of LEZs guidelines should highlight the need for schemes to be based on common emissions standards, have explicit objectives for air quality improvement and provide incentives for using the cleanest vehicles. Guidelines should also emphasize the need for establishing an adequate perimeter for LEZs. The very small scale of the schemes currently under consideration in the CAMe area means they will have little impact on air quality.

While detailed evaluations would be needed to determine the size of the benefit of shifting to a city-wide low emission zone in Mexico City, the following sections provide insights into the potential benefits. These are based on discussions between experts and local authorities during the workshop on possible ways in which an LEZ could become part of the strategy for improving air quality in the ZMVM. If an LEZ were to replace the HNC for regular, day to day traffic management, Stage 1 and Stage 2 pollution alert restrictions could be retained for severe pollution episodes, as occasional restrictions provide relatively little incentive to purchase a second vehicle.

Box 1.5. **Integrated Impact Assessment for the ultra-low emission zone in London.**

As part of the analysis for the implementation of the ultra-low emission zone (ULEZ), Transport for London (TfL) undertook an Integrated Impact Assessment in order to have a general overview of the possible impacts in a number of areas including environmental, health, equality and economic and business.

Consultations through workshops were conducted with the main stakeholders including government agencies, local authorities, consultants, and transport and industry associations. The result was the identification of anticipated effects associated with the ULEZ. Each one of the impacts was classified according to its scale (minor, moderate or major effect) and duration (short and medium for less than five years, and long term for more than five years).

The most relevant impacts identified are:

a) **Environment:** ULEZ would result in improvements in the air quality due reduction in NO_2 and CO_2 through the use of low and zero emission vehicles and the use of public and non-motorised transport.

b) **Population and equality:** The most relevant negative impacts are related to vulnerable groups that could not afford a compliant vehicle and could be affected by the reduction in the number of vehicles or the cost they need to pay to enter the ULEZ; these groups include female night workers, low-income workers, school children from low-income families, disabled persons who might have difficulties finding an alternative mode of accessible transport, taxi drivers who may choose to retire rather than upgrade to a compliant vehicle, and groups that rely on charitable or voluntary services to access London.

c) **Economic:** ULEZ would have an impact on the economy by gaining a benefit associated with improved health outcomes but would result in more costs for SMEs and tourists due to the reduction of non-compliant utilitarian and tourist vehicles.

Several measures were proposed to mitigate the negative impacts, these include:

- Investment in infrastructure for public transport, walking and cycling.
- Increasing the coverage and frequency of night bus services and providing metro services during all night on some lines.
- Promotion of grants to obtain a compliant vehicle for taxis, SMEs, and other vulnerable groups.
- Communication strategies to provide useful information to affected groups.
- Free transport for school children on TfL services (bus, metro, tram).
- Improve physical accessibility in public transport.
- Subsidised taxi services for people with reduced mobility.

Detailed information can be obtained from Jacobs (2014), "Ultra Low Emission Zone Integrated Impact Assessment", TfL consultations. https://consultations.tfl.gov.uk/environment/ultra-low-emission-zone/user_uploads/ulez-iia-report_final.pdf

Introducing a low emission zone focused on heavy-duty vehicles

Heavy-duty diesel vehicles contribute a large share of transport sector emissions. Poor performance in urban traffic conditions of the control technologies deployed until the most recent regulations mean emissions have been seriously underestimated. Diesel cars and delivery vans have similarly tended to emit more pollutants than expected. In response an increasing number of cities are implementing low emission zones (LEZ), providing incentives for accelerating the introduction of and the newest, less polluting technologies. While in some cities LEZs also include passenger cars and motorcycles (e.g. Berlin, Milan) they have often focused on heavy-duty vehicles (HDVs) and delivery vehicles (e.g. London, Stockholm). In the case of London, the introduction of passenger cars in the LEZ is now planned. In Paris the first phase of the LEZ focused on HDVs but was recently expanded to include light-duty vehicles (LDVs) and motorcycles.

In Mexico City, diesel HDVs (including heavy trucks, buses, and freight vehicles of above 3.8 tonnes) are responsible for close to 17%, 24%, and 38% of PM_{10}, $PM_{2.5}$ and NO_X emissions respectively (SEDEMA 2014) and the figures are likely to be much higher on the basis of real-world emissions testing. This suggests a strong case for an LEZ that would, at least in a first phase, focus on reducing emissions from these vehicles. With the I&M programme and windscreen sticker system for classifying vehicles according to their environmental performance, key tools are already in place for administering such a scheme. LEZs in Germany, for instance, have been implemented using a similar colour windscreen identification system and manual enforcement by the police. Nonetheless, as with the current HNC, the use of automatic number plate recognition (ANPR) cameras would make enforcement more effective. These are already used to enforce speed limits on some of the city's urban motorways. The cost of enforcement with ANPR is driven largely by the data management system required to meet the local legal standards of proof for identification of drivers in infraction (see ITF, 2010).

International experience has shown that to be effective the area covered by a LEZ needs to be relatively large in relation to the total extent of a city (see Chapter 2). London currently has the largest LEZ, covering most of Greater London. Maintaining the current area of *Hoy No Circula* scheme for the establishment of an LEZ (i.e. the whole of the ZMVM) might be a good option. The ZMVM accounts for a significant share of the total vehicle-kilometres travelled by freight vehicles for the whole country so this could serve a second purpose of incentivising the introduction of new technologies in the national fleet (particularly in the surrounding States that are part of the CAMe).

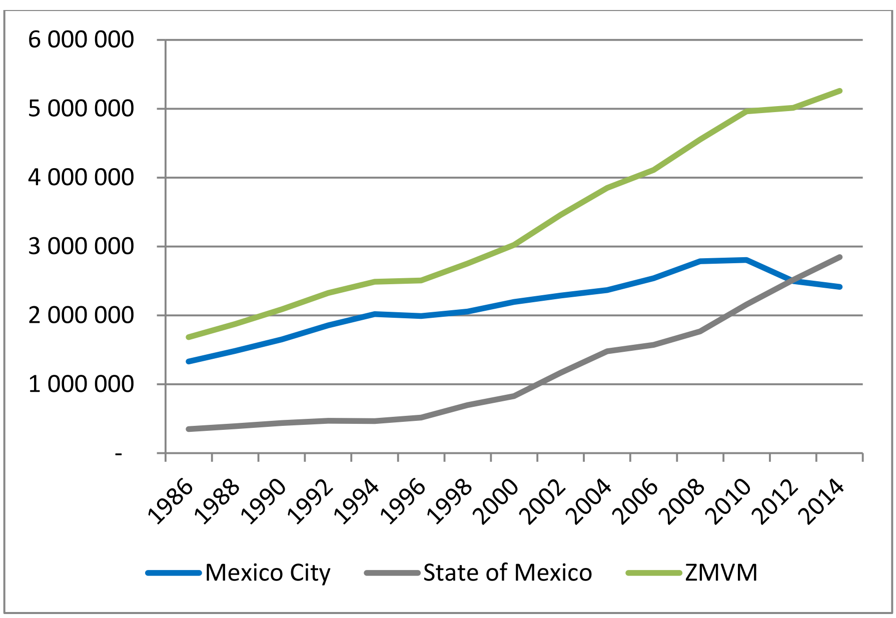
Low emission zones can completely ban certain categories of vehicles, which is the case of LEZs in Stockholm and Paris. Alternatively, these can also impose a charge for entering the designated area for vehicles that do not meet a certain emission standard, as in London. In each case, introducing such a scheme through progressive phases, announced well in advance, has been important. Box 1.5 shows the different phases for implementation of the LEZs in Paris and London. In the case of the Metropolitan Area of Valle de México, either approach or a combination of the two could be implemented. Whatever the exact design of the scheme, this should have a clear objective of accelerating introduction of Euro VI and phasing out HDVs without effective OBD systems and particle filters. Experience in London shows that in the case in which a charge for entering the area is set, this should be set at a level where the compliant vehicle becomes the cost effective option, i.e. where frequent users will find paying the charge every time they need to go in more expensive than changing their vehicle.

A number of programmes have been introduced in Mexico to promote fleet improvement and renewal for diesel HDVs (the Clean Transport Programme, the Auto regulation Programme, the Vehicle Substitution Scheme, and the Programme for Modernising the Federal Road Transport Fleet). These could be linked to an LEZ, which would facilitate introduction of the policy and accelerate vehicle turnover while reducing the economic impacts for vulnerable groups.

Shifting from the HNC to alternative restrictions for light-duty vehicles

The vehicle fleet in the ZMVM has increased significantly over the last decades (Figure 1.3). Private cars and SUVs have shown particular growth and today represent over 75% of vehicles in the area. There has also been a significant increase in the fleet of taxis and motorcycles (Figure 1.4). In Mexico City, LDVs (including taxis and SUVs) are estimated to be responsible for 12%, 7% and 26% of PM_{10}, $PM_{2.5}$ and NO_X emissions respectively (SEDEMA, 2014). As in many cities, pollution is exacerbated by high shares of vehicles with limited emission control technologies and, particularly as motorisation grows and road space becomes scarce, increasing congestion. Passenger cars in the ZMVM are mostly gasoline fuelled, which in principle is an advantage compared to cities that have high shares of diesel cars. Many of the larger SUVs are diesels and it is important to note that new gasoline direct injection engines in jurisdictions like Mexico where they are not subject to regulation to limit particle numbers produce more ultrafine particles than the latest diesel cars.

Figure 1.3. **Registered vehicles in circulation 1986-2014**

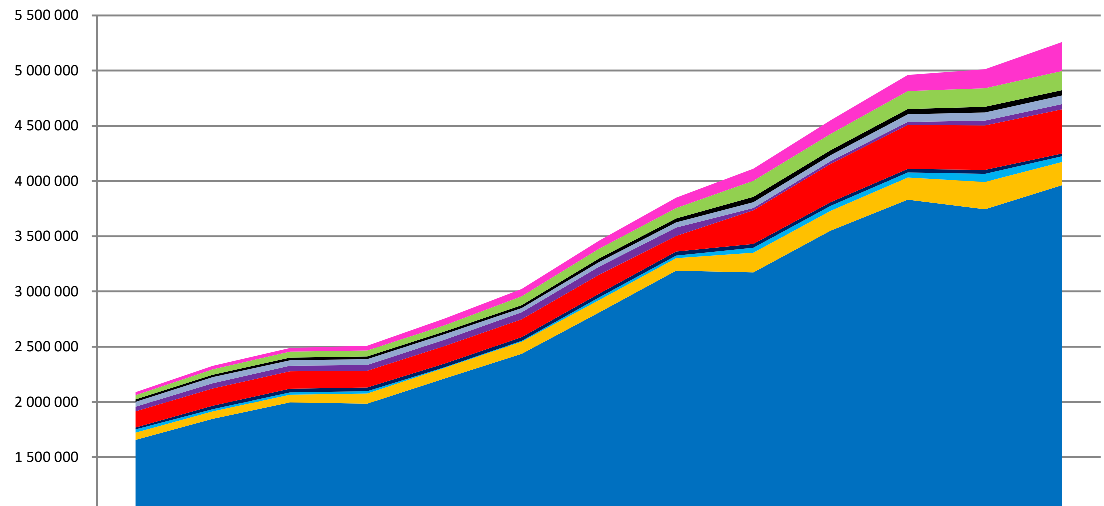


Source: SEDEMA (2017).

This information was provided by the Ministry of Environment in Mexico City and corresponds to that collected during I&M procedures. The numbers are significantly lower to those reported by the Institute of Statistics and Geography (INEGI), presumably due largely to the fact that data reported by INEGI does not take into account deregistration of vehicles. Contrarily this is better reflected in data collected through the I&M system since only vehicles in circulation are enrolled in the programme. Also, the number of vehicles shown corresponds to the definition of the ZMVM that includes Mexico City and 18 municipalities of the State of Mexico, rather than the area defined by CONAPO.

Light-duty vehicles (and motorcycles in several cities) have been made subject to restrictions in LEZs or to pollution charges as a way for accelerating introduction of new technologies and limiting the entrance of the most polluting cars into certain areas. In Berlin the LEZ bans all vehicles (including passenger cars) that do not have a 4 (green sticker) classification. In terms of passenger cars category 4 corresponds to vehicles that comply at least with Euro 1 standards and have a catalytic converter. In Paris, Pre-Euro 2 cars and all cars registered before 1997 are banned from the LEZ. Starting in July 2017 this will also apply to Pre-Euro 3 diesel cars, as well as those registered before 2001.

Figure 1.4. **Registered vehicles by type in ZMVM 1990-2014**



	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014
BRT	-	-	-	-	-	-	-	-	80	221	233	427	551
Motorcycles	27 978	31 352	32 725	42 817	61 131	65 749	72 900	93 927	109 444	123 407	145 698	172 162	262 212
Vehicles more 3 tons	37 745	49 714	54 452	54 202	56 554	81 300	88 368	94 365	145 580	147 778	162 991	168 176	173 822
Buses	21 603	20 207	23 672	23 974	23 057	25 077	31 704	34 740	47 859	44 304	47 009	50 734	47 136
Trucks	44 621	56 340	49 667	53 333	51 017	38 768	42 500	47 618	53 275	54 985	69 782	74 305	79 187
Vehicles less 3 tons	41 715	47 412	50 573	52 333	57 458	63 648	73 114	76 209	20 922	24 175	27 021	43 597	46 967
Pick Up	146 623	156 162	157 551	151 342	159 058	161 812	171 271	140 769	304 122	347 082	398 276	402 546	400 329
Microbuses	16 418	31 077	33 107	33 249	32 722	33 062	33 448	36 394	34 040	32 753	31 625	35 175	24 113
Van	29 356	19 643	21 094	21 117	5 594	7 942	24 365	23 219	45 142	45 165	45 801	73 584	52 165
Taxis	66 150	67 871	69 745	92 222	96 639	109 792	112 452	113 510	178 342	179 535	200 769	247 562	210 168
Cars and SUV	1 656 644	1 847 334	1 995 991	1 984 434	2 211 798	2 435 720	2 809 007	3 188 555	3 172 965	3 550 708	3 831 425	3 744 482	3 962 903

Source: SEDEMA (2017).

Implementing policies that target congestion and road-use explicitly

In the case of Milan, a first scheme involving driving restrictions was implemented in 2008 as a pollution charge called ECOPASS. The central ring road of the city was the area chosen as the perimeter where the pollution charge would be levied. Free entrance was granted to the cleanest vehicles (class I: hybrid, electric, LPG, and CNG vehicles; and class II: gasoline car Euro 3 and 4, diesel car Euro 4 with advanced particulate filters, gasoline light-duty freight Euro 2, 3 and 4; and diesel light freight Euro 4 with advanced particulate filters). Entrance to all other vehicles was granted only on payment of a charge, which increased according to the level of emissions. The measure had significant effects in accelerating the transition to better technologies. In the initial stages traffic levels were also reduced. A significant modal shift towards public transport in the area (on average 23 000 additional passengers on the underground metro line) was one of the reasons behind this. The reduction in congestion was in turn beneficial to surface public transport, which saw an increase in its commercial speed (about 13% for the tramway and 20% for bus and trolleybus).

Box 1.6. **Phases for implementing LEZs in London and Paris**

London

The London low emission zone (LEZ) is an area that covers most of Greater London (1 572 square miles). It operates 24 hours per day, every day of the year, and is controlled with cameras that read number plate; this tells automatically whether the vehicle meets the LEZ emissions standards, is exempt, is registered for a discount, or if it must pay the daily charge.

Date	Type of vehicle	Vehicles that must pay a charge to enter
2008	Heavy vehicles	Euro III or lower for PM_{10} and vehicles registered as new before 2000. The daily charge is GBP 200.
2012	Heavy Vehicles	Euro IV or lower and vehicles registered as new before 2005
	Delivery Vans	Euro 3 or lower for PM_{10} and vehicles registered as new before 2001. The daily charge is GBP 100.

An ultra-low emission zone (ULEZ) was announced in 2015 and will be implemented by 2020 in Inner London. This will restrict the circulation of all vehicles.

Cars and small delivery vans	Petrol, Euro 4 or lower + registered as new before 2006 or daily charge of GBP 12.50. Diesel, Euro 6 and registered as new before 2015 or daily charge of GBP 12.50.
Large delivery vans and minibuses	Petrol, Euro 4 or lower + registered as new before 2007 or daily charge of GBP 12.50. Diesel, Euro 6 and registered as new before 2016 or daily charge of GBP 12.50.
Heavy vehicles	Euro VI or lower and registered as new before 2014 or daily charge of GBP 100.
Motorcycles	Euro 3 or lower and registered as new before 2006 or daily charge of GBP 12.50.

In June 2016, the Mayor of London announced new air quality measures including the intention to levy an emissions surcharge (known as the "T charge") on older vehicles entering or driving in Central London through an addition to the existing Congestion Charge and to bring forward implementation of the ULEZ to 2019 and expand it. The proposal is to expand the ULEZ zone to all of Greater London for heavy vehicles and extend it for all vehicles from the small central zone to the North and South Circular Roads. A public consultation was held in the last quarter of 2016 (TfL, 2016).

Paris

The LEZ introduced by the *Mairie de Paris* in September 2015 covers the City of Paris, the central part of the metropolis, covering an area of 105 km^2.

Date	Type of vehicle	Vehicles that are banned
September 2015	Heavy vehicles	Pre-Euro III and vehicles that entered circulation before 1 October 2001. All days from 8:00 to 20:00.
July 2016	Private vehicles and light-duty vehicles	Pre-Euro 2 and vehicles that entered circulation before 1 January 1997. From 8:00 to 20:00 on working days.
	Motorcycles	Euro 1 and motorcycles that entered circulation before 1 June 1999. From 8:00 to 20:00 on working days.
	Heavy vehicles	Pre-Euro III and vehicles that entered circulation before 1 October 2001. Every day from 8:00 to 20:00.
July 2017	Private vehicles and light-duty vehicles	Pre-Euro 3 diesel and vehicles that entered circulation before 2001. From 8:00 to 20:00 on working days.
	Heavy vehicles	Pre-Euro 4 and heavy vehicles that entered circulation before October 2006. Every day from 8:00 to 20:00.

By 2020, the goal is to restrict the use of all diesel vehicles and to tighten restrictions on gasoline vehicles:

Motorcycles	Euro 3 or lower and vehicles that entered circulation before 2007.
Cars	Euro 4 or lower and that entered circulation before 2011.
Light-duty vehicles	Euro 4 or lower and LDV that entered circulation before 2011.
Trucks and buses	Euro V or lower and vehicles that entered circulation before 2014.

Nonetheless, not levying a charge on road usage but rather on pollution meant that as a higher share of vehicles became compliant with standards, gaining free entrance, traffic reductions declined. In the interests of targeting congestion specifically, the authorities made the transition from the ECOPASS system to the “Area C” scheme in 2012. The new scheme is a combination of a LEZ, banning entrance to the inner ring for the most polluting vehicles, and a congestion charge, levied on all other vehicles when they enter the zone.

In the case of London, traffic restrictions have been introduced both to incentivise cleaner technologies and to reduce congestion. The LEZ was established with the first objective making freight vehicles cleaner. An ultra-low emission zone (ULEZ), setting much tighter standards for free entrance into the central area of the city and covering all vehicle types is planned to be implemented by 2020 (see Box 1.5). London also implemented a congestion charge in 2003 for both light and heavy vehicles. The scheme has a flat rate to be paid when entering or traveling within an inner city zone and is enforced through closed circuit TV and automatic number plate recognition. The introduction of an emission surcharge as a supplement to the congestion charge has been proposed as a transition stage in introducing the ULEZ.

The congestion charge in London had significant effects in reducing congestion during its first decade of implementation. Modal shifts from private to public and active modes of transport were a significant part of this result. However, since 2012 vehicle speeds on major roads in Central London have been falling and journey time reliability within the area has worsened (Transport Committee, 2017). There are multiple reasons behind this. There has been a significant reallocation of road space in accordance to more sustainable and inclusive mobility goals, i.e. prioritising pedestrian, cyclists and public transport users. This has off-set to a certain degree the decrease in private car use. Going back on those policies would not be desirable. Transport for London has identified a number of actions with the potential to reduce congestion further. For example, better managing delivery services (e.g. with delivery consolidation centres and “click and collect” deliveries by supermarkets at Tube and rail stations in the suburbs, where commuters can pick up goods on their journey home) to control the rapid increase of van delivery traffic; and better regulating private-hire vehicles (which are rapidly growing in number and are not subject to the congestion charge).

A report by the London Assembly proposes that in order to increase its effectiveness, the congestion charge scheme should be modified, introducing differential charge rates, becoming closer to a road pricing scheme. With the current flat rate, the system fails to price road usage according to the availability of road space during the day or to distance driven. Thus it also falls short in incentivising shifts in road usage towards higher capacity times and better matching demand and capacity during the day (Transport Committee, 2017).

Mexico City and the wider ZMVM will need to develop further policies to reduce congestion and promote modal shift in their pollution reduction strategies as well as maintaining incentives for fleet renewal. Policies that do not explicitly price road space usage are not a solution to congestion in the longer run, and the HNC programme, or an alternative LEZ, is no exception. Like London, Mexico City is changing road space allocation towards use by pedestrians, bicycles and public transport. The reduction in road space dedicated to car use will need to be accounted for in evaluating effectiveness of schemes to restrict car use.

There are a number of ways in which elements of the vehicle restriction schemes in London, Milan, Paris and Germany could be used in Mexico City and the ZMVM. Alternatives could include creation of a wide-area LEZ for heavy-duty vehicles, incorporating light-duty vehicles into later phases while retaining the HNC system for responding to peak pollution episodes. Road pricing might be introduced on highly congested corridors and/or areas where traffic diversion can be contained.

Any scheme should be based on analysis of sufficient detail to identify what types of vehicle traffic are most relevant to generating congestion and pollution and the levels of charges needed to incentivise fleet renewal and modal shift, where alternatives to car use are available. Improving and updating data and analysis will be necessary. Both the latest study on traffic activities and the origin-destination travel survey realised at metropolitan level are more than 10 years old. Ex-post evaluation is also relevant for modifying schemes and implementing complementary policies as conditions change.

General traffic management

Parking

The current PROAIRE program in the ZMVM puts an appropriate emphasis on managing traffic to reduce congestion and stop-go driving conditions and improve the flow of vehicles on the city's roads, including through intersection alignments, managing traffic lights and preventing unauthorised roadside parking. Containing the number of vehicles on the road to levels that can be accommodated by the physical capacity of the system is fundamental. Especially for big cities, parking policies are the starting point and a powerful tool. Charging for the consumption of valuable road space for parking is essential.

Evidence across the world demonstrates that efficient parking prices can significantly reduce traffic flows, reducing cruising and encouraging modal shift towards public and non-motorised modes. In some US cities, 30% of the cars in congested traffic have been found to be cruising in the search for parking spaces (Shoup, 2007). Parking pricing can help achieve the optimal level of unoccupied parking spaces (15%) required to minimise the amount of cruising time in urban areas (Shoup, 2005; Kodransky and Hermann, 2011). In addition, adjusting supply of both on-street and off-street parking according to supply of public transport services and availability of walking and cycling facilities can help cities in attaining modal shift from private vehicles to these modes of transport.

Mexico City and the ZMVM need to develop an effective strategy for managing parking. As a first step the Ecoparq programme, which has introduced parking meters in western central areas of Mexico City, should be expanded to cover all of the city and the ZMVM. An important improvement to current parking pricing (both for on-street and garage parking) is moving from fixed to differentiated rates that could better reflect the value of public space in different areas (according to demand and land-use) and incentivise modal shift in areas that are well served by public transport and have good facilities for using active modes. An important obstacle to doing this in the ZMVM is that maximum on-street parking fees are set in State fiscal codes. Regulations are needed to give city administrations flexibility to establish variable parking prices.

Cities like Lisbon, for example, have established parking rates for different areas of the city depending on demand. The charge is higher in zones with high demand and higher provision of public transport. In San Francisco, authorities have taken advantage of mobile communications technologies to introduce smart parking meters with real-time fare adjustments in several of the busiest commercial neighbourhoods in the city. Evaluation of the SF Park project show significant success. For instance, target occupancy rate (60-80%) was met 31% more often; incidence of blocks with no available parking were reduced 16%; and the average time spent searching for parking decreased 43% (5 minutes). In addition vehicle travel and greenhouse gas emissions from cruising while searching for parking is estimated to have decreased 30%. It is important to highlight that average meter rates dropped (by 4% for on-street meter rates and by 12% for garage rates) as peak rates were introduced. Removing legal restrictions to allow flexibility in tariffs for on-street parking will be crucial for authorities in the ZMVM for setting efficient pricing policies.

Parking space regulations should set an objective of reducing supply where density and land-use mix is high and public transport, walking and cycling facilities are available. With this objective, cities like Zurich and Hamburg have implemented parking caps in business districts that have good access to public transport (OECD, 2015).

International experience also suggests that minimum requirements for parking space in buildings should be abandoned. Eliminating minimum parking requirements is increasingly common in metropolitan areas that seek to move away from car-oriented development and achieve more transit-oriented development patterns. Examples include Denver, Nashville and Sao Paulo. New York, Portland and Oregon have in addition established maximum parking spaces for property developments in central areas. In Paris and Ottawa, regulations are also linked to the availability of public transport. The London Plan (the spatial plan that guides development in London), uses an index measuring public transport accessibility (PTAL) for calculating recommended parking capacity in new developments under the principle that higher PTAL level areas provide less parking spaces, in line with the overall goal of encouraging modal shift towards public transport (TfL, 2015).

Speed limits

Fortuitously, speed limits were lowered across Mexico City's roads in 2015 under improved road safety policy. Speeds on urban freeways were reduced to 80 km/h, trunk roads are restricted to 50 km/h and feeder roads 30 km/h with a 20 km/h limit on sensitive streets, for example near schools. These are the limits internationally recognised as appropriate to these roads on the basis of damage and survivability in collisions and the typical mix of users on these types of roads. These speeds are also close to optimal for maximising the flow of vehicles on congested roads. On a crowded highway, vehicles interfere with each other particularly when changing lanes. The result is a need for longer gaps between vehicles and frequent braking to avoid collision, both of which reduce flow. Monitoring traffic in these conditions shows that lowering speeds cuts stop-go conditions, increases flow and reduces average journey times. Reduced speeds are used routinely to manage congestion and increase flow on urban freeways in a number of cities, for example on London's M25 ring road where speeds are reduced from 70 to 50 mph. They are also used to cut pollution during smog episodes, for example in Paris on its Périphérique ring road and on its radial motorways where limits are reduced 20 km/h below the usual level. Speed limits are an effective short-term measure for cutting emissions, to the extent they are enforced and respected; they smooth traffic, moderate the cycle of braking and acceleration, reduce hard accelerations and cut excess speeds – all factors associated with excess emissions.

The impact on air pollution of speed restrictions has been modelled and monitored in a number of cities. Goncalves et al. (2008) model the effects of the introduction of an 80 km/h speed limit on trunk roads in Barcelona. This found small improvements in NO_2, SO_2, PM_{10}, $PM_{2.5}$ and CO emissions for the region as a whole and a marginal impact on O_3 concentrations in the air. The small overall change in emissions was thought to be due to congestion keeping speeds down even before introducing the limit and the relatively small part of the air catchment area over which the limits apply. Close to the main roads, improvements were significant: 5.7% for NO_2, 5.3% for SO_2 and 3.0% for PM_{10} for 24-hour average concentrations. The reduction in NO_X emissions resulted in a local increase in O_3 concentrations as, like Mexico City, in Barcelona O_3 formation is limited by VOC concentrations (and NO_X breaks down ozone on balance in the absence of sunshine); nevertheless downstream in the pollution plume O_3 concentrations were unaffected.

Bel and Rosell (2013) measure the impact of changes in speed limits in Catalonia by sampling data from the air pollution monitoring network before and after changes to speed limits in the region. Changes in government resulted in a complicated sequence of changes in to the limits. In July 2007 the regional government of Catalonia passed an Action Plan for Improving Air Quality in the Barcelona Metropolitan Region, which included a reduction in the maximum speed limit to 80 km/h on motorways. Limits were reduced from 120 and 110 km/h to 80 km/h for the region, although roads were already limited to 80 km/h or lower in Barcelona. This policy was overturned in 2011 but at the same time the national government reduced maximum speed limits from 120 km/h to 110 km/h. The 2007 Action Plan included an experiment with variable speed limits on the two southern access roads to Barcelona that began in 2009. The variable limits adjust to traffic congestion, weather, crashes and other incidents that affect flow in real time to maintain as smooth a traffic flow as possible. Speed limits are signalled on variable message signs and enforced by radar and automatic fines. Speeds are adjusted in increments of 10 km/h between 80 km/h maximum and 40 km/h minimum. The new government progressively extended the system to other main roads at the same time as overturning the general 80 km/h limit. Bel and Rosell found the generalised 80 km/h limit to be counterproductive but the variable speed limits highly effective in cutting emissions, because of the reduction in stop-go traffic conditions on top of the overall moderation of speeds. The variable speed policy was found to have reduced NO_X and PM_{10} concentrations at monitoring stations near the controlled roads by 7.7 to 17.1% and 14.5 to 17.3% respectively.

Dijkema et al. (2008) assessed the impact on air quality of lowering speed limits on the motorways around Amsterdam. In November 2005, the national Transport Ministry reduced the maximum speed limit on specific sections of urban highway from 100 to 80 km/h. The national maximum speed limit for heavy-duty vehicles was already 80 km/h. The National Transport Research Center estimated emission reductions would be 14% for PM_{10} and 10–15% for NO_2 leading to an improvement in atmospheric concentrations of 0.5–1% for PM_{10} and 2–4% for NO_2 adjacent to the ring road. The Dijkema study assessed the impact of the speed limit change with data from the air quality monitoring network before and after the change, adjusting for differences in weather and traffic flows. The study found reductions in particulate matter emissions on all parts of the road network, probably related to incentives for cleaner cars, but much larger reductions in PM_{10} and black smoke at the road sections with the lower speed limits. The observed reduction in the mean roadside concentration of PM_{10} at the speed controlled sections was 7%, much larger than predicted by the model. This might even be an underestimate as a noise wall was installed at the test site just prior to the introduction of the speed limit; the wall probably acts to raise concentrations of particulates close to the road. In contrast to particulate matter, no clear effects on nitrogen oxides were observed but confidence intervals were wide, owing to the high day-to-day variation of the measured NO_X concentrations. Overall the authors conclude that the study demonstrates a significant reduction of PM_{10} and $PM_{1.0}$ as a result of reducing the speed limit at the urban ring road.

In France, the impact of speed limits on air pollution has been measured around the western city of Rennes, where speed limits on the city’s ring road and link motorways were reduced in 2016 from 110 to 90 km/h to reduce air pollution. This followed a year of experimentation during which sections of the roads were also limited to 70 km/h. Impacts on noise, air pollution, congestion and crashes were assessed. The reduction of speeds to 90 km/h saw NO_2 emissions fall by up to 40% whilst reductions to 70 km/h saw mixed results. As a result 90 km/h has been adopted as the limit across the network.

In the United Kingdom, Highways England is considering a 60 mph (96 km/h) limit on motorways around Sheffield and possibly other cities to reduce air pollution, following a draft report from the National Institute for Health and Care Excellence in December 2016 (NICE, 2016). The report concluded that accelerating or decelerating too rapidly leads to inefficient driving and fuel consumption with harmful emissions being released into the environment unnecessarily and sets out guidance on a strategic range of evidence-based practical measures to encourage low or zero emissions transport. The focus of the draft guidelines is on a local level, where actions taken by councils and transport providers will have a greater impact across local communities. The guidelines cover planning, clean air zones, congestion charging, reducing emissions from public transport and government fleets, smooth driving and speed reduction and cycle routes. In addition to lowering speed limits on urban motorways the report suggests more 20 mph (32 km/h) speed limits in congested residential areas, re-designing speed bumps to stop cars speeding up and slowing down between them, restrictions on engine idling during short stops such as outside schools and hospitals, more charging points for electric cars in residential areas and training drivers to be more fuel efficient by driving more smoothly. The NICE report includes a review of evidence on the efficacy of such measures. Mandatory air quality objectives

Mandatory air quality objectives have been a useful tool for improving air quality in the United States, in the form of National Ambient Air Quality Standards Non-Attainment Areas. Air quality limits were set and a timeframe for attainment agreed, with penalties for non-compliance in the form of withheld federal funds for non-compliant cities. This drives negotiation over budgets within local government for measures to meet the objectives and provides the framework for communicating on the issue.

Similarly the European Union’s Ambient Air Quality Directive requires national governments for air quality management areas in regions where standards are not met and sets timeframes for improvement. Member States that miss deadlines are ultimately liable to substantial fines. The system might be adopted in Mexico where the ZMVM is not the only metropolis to suffer chronic air pollution problems but the only region to have adopted an air quality management and pollution alert system.

Enhancing and promoting sustainable transport alternatives

Containing demand for private car use and providing good quality alternatives through public transport and cycling is an essential part of strategies to limit air pollution. Planning land use development around investments in public transport is fundamental to limiting the growth of transport demand as the metropolitan population increases and incomes rise. Creating urban environments that are more accessible on foot and by non-motorised modes of transport also alleviates the need for using cars.

Metropolitan co-ordination

The lack of integrated, long-term transport and spatial planning in the ZMVM has been central to creating unmanageable sprawl and car-dependency that exacerbate congestion and pollution. To reverse this trend, improving co-ordination between jurisdictions and between authorities in charge of different modes of transport is a first-order priority. In addition, integrating planning of transport and land-use is also key.

International experience has shown that transport authorities that plan and regulate mobility across the whole of a metropolitan area and have authority over different transport modes tend to be more successful. This kind of authorities has been developed in London, Paris, Singapore and Curitiba, for example. In Mexico the national legal framework does not allow this possibility, although proposals to modify the law that regulates human settlements in this direction have already been put forward. In the meantime, improving the current metropolitan framework to co-ordinate planning and policy implementation should be prioritised.

Metropolitan governance for transport in the ZMVM was supposed to be led by the Metropolitan Commission for Transport (COMETRAVI), which was created in 1994 and had objectives such as improving transport services and road infrastructure in the metropolitan area, promoting standardisation of legal frameworks for transport, and providing information for the development of a Transport Master Plan for the ZMVM. However, the commission fell short in meeting its objectives and its activities are currently suspended. Restoring this institution would be important to construct an effective metropolitan framework for transport planning and policy implementation.

One shortcoming with the COMETRAVI was the lack of permanent staff and financial resources. Ensuring that these two elements are part of a restored Metropolitan Transport Commission will be key. The institution would of course need to be effectively co-ordinated with CAMe activities and build on the standardisation of transport-related policies across the CAMe region that this institution has already advanced. As an alternative to restoring the transport commission, CAMe could be assigned the objectives that were originally set for COMETRAVI. In this case, adequate human and financial resources for carrying out the corresponding activities should be assigned to CAMe.

Among the key pending issues related to metropolitan governance are:

- Harmonising the legal frameworks across the ZMVM. A New Mobility Law for Mexico City was issued in 2015 that explicitly resets priorities for allocating investment and road space in favour of pedestrians, cyclists and public transport, then freight delivery and lastly private vehicles. Legal frameworks across the ZMVM also need to reflect these new priorities.

- Integrating transport services across jurisdictions. Co-ordination between the authorities in the ZMVM is needed to develop a metropolitan wide transport network, fostering physical, operational and financial integration across modes and corridors that cross multiple jurisdictions, including the Metrobus and Mexibus BRT systems, priority bus corridors and the metro. Reconfiguration of bus routes according to origin-destination demand, regardless of administrative boundaries is also needed.

- Development of a Mobility Master plan for the ZMVM. All major conurbations in Europe now have long-term urban transport development plans contiguous with their commuting hinterlands. A Mobility Master Plan for the ZMVM has yet to be completed. This is key to setting out a long-term, shared vision for more sustainable mobility and identifying the funding that will be needed to deliver it. Funding allocation, both from local administrations and federal funds (Fondo Metropolitano, PROTRAM) should be linked to the priorities set out in the plan (OECD, 2015).

Improving co-ordination between transport and land-use authorities

An important short coming for urban development in the ZMVM has been the persistent division between spatial and transport planning. In particular the development of poorly connected, isolated and low-density housing in the peripheries has generated high shares of long-distance trips that are served by either highly polluting *microbuses* or cars (in many cases relatively old and also highly polluting). The lack of integrated transport and land-use planning has also resulted in high and unanticipated costs for the population. In some peripheral areas of the ZMVM (e.g Huehuetoca and Zumpango), lack of transport accessibility has played a crucial role in a high number of homeowners abandoning houses on which they had already started paying monthly credit fees. In addition this has placed unnecessary financial stress in transport systems like the suburban rail, that due to the lack of adequate complementary land-use planning operate at significantly lower than projected demand.

Linking construction permits to the conclusion of agreements with developers on strategies to generate sufficient transport capacity and cope with negative impacts on traffic and air pollution is central to integrating land-use and transport planning. The New Mobility Law for Mexico City introduced mobility impact assessments for this purpose; effective development of this framework, making it an integral part of the process for awarding construction authorisations, will be important. This will require co-operation between the City's Ministry of Urban Development and Housing and the Ministry of Mobility.

Financial capacity for investing in sustainable mobility

Authorities in the ZMVM also need to enhance their financial capacity for investment in public transport and in walking and cycling infrastructure. Public transport systems need more sustainable funding models. Firstly, regular, planned and modest fare adjustments should replace the practice of maintaining fixed rates for long periods followed by unexpected increases. This will provide operators with greater certainty for future cost recovery and allow authorities to set concession terms based on cost structure rather than by negotiating fixed levels of profits, which has contributed to financial stress in bus rapid transit projects. Secondly, replacing generalised subsidies with targeted subsidy schemes could help reconcile quality and affordability. Following other cities in Latin America, the ZMVM could benefit from the introduction of smart cards to deliver subsidies for travel to lower income and other vulnerable groups. The framework developed by Mexico's *Prospera* poverty alleviation programme could be used to identify beneficiaries. Tariffs that differentiate between peak and off-peak travel would also improve financial sustainability.

Overall, a more transparent and balanced model for subsidising public transport is required. Funding is currently characterised by two extremes: repeated calls on "temporary" funding for projects that had been expected to operate without subsidies, as is the case in various BRT corridors; and higher than necessary overall levels of subsidy based on overestimates of needs for large segments of the population, who could pay rates closer to cost-recovery. The relatively low contribution from fare box revenues undermines budgets for maintenance and upgrades, particularly for the metro.

The funding base for investment in sustainable transport might also be enlarged by earmarking revenues from charges on private vehicles (fines for contravening HNC restrictions and parking fees, as well as any future charges linked LEZs or road pricing schemes). Lowering or eliminating the thresholds for vehicle ownership taxes (*tenencia*) across the ZMVM is also important. For many years the revenues from this tax were allocated to public transport. In 2014 the implicit subsidy from exempting cars with a value below these thresholds amounted to about half of the gap between the resources received and the resources requested by the public company operating the metro.

Finally, authorities could make more use of land value capture mechanisms to fund public transport, an approach used in many cities including London, for example, which uses Community Infrastructure Levies added to business tax rates to fund specific investments. Betterment charges (*contribución de mejoras*) have been available are since 2014 for funding pubic and non-motorised transport projects inside Mexico City and the model could be extended to other States of the ZMVM.

Accelerating bus reform and making sure replaced microbuses are scrapped

BRT corridors were first introduced in Mexico City in 2005. Central to this has been the progressive shift from a bus system operated by a large number of small under-regulated operators to one run by larger and more professional enterprises which are now subject to higher quality and safety standards. The process has also brought important environmental and air quality benefits since funds from the vehicle substitution programme have been used to incentivise the substitution of high polluting *microbuses* previously operating in the corridors with BRT buses.

Overtime, the BRT system in Mexico City (*Metrobús)* has been expanded (six corridors are now implemented). A similar system (*Mexibus*) has been implemented in municipalities of the State of Mexico in the ZMVM (four corridors). In addition several Bus Rapid Service corridors (bus services with preferential right of way) are being introduced in Mexico City. Making sure that *microbuses* replaced are effectively scrapped has been a challenge in the expansion of the BRT system and the introduction of BRS corridors, compromising air quality and environmental objectives. In addition, although the ZMVM has made important progress, shifting the whole of the microbus system into new concession rules is still far from completion. Microbuses still account for the majority of total public transport trips in Mexico City, and thus are important contributors to air pollution. In line with the objective of advancing bus reform, the New Mobility Law in Mexico City establishes that new bus concessions can only be granted to companies.

Accelerating bus reform throughout the ZMVM is an important priority. It is in particular relevant to make sure scrapping of microbuses operating in routes that are shifted to operation by more professional and regulated companies are effectively scrapped.

Among the main challenges to continue bus reform are the following is building on regulatory expertise acquired and continuing to expand it. As in other cities that are going through bus reform, negotiations with incumbent operators have proven challenging. Concession terms agreed have in many cases compromised financial sustainability of the system. In particular payment for operation to concessionaires has tended to be agreed under the logic of ensuring pre-reform revenues to incumbent *microbus* operators (now incorporated into the companies in the new systems) rather than based on an evaluation of operation costs. Nevertheless, in the case of Mexico City, terms agreed by the public regulator (also called *Metrobús*) have shown adjustments in the right direction as new corridors have been implemented, which reflects the progressive expansion of regulatory capacity. In this case having a regulatory body with specialised staff has been an asset.

Expansion of Mexibus, as well as of BRS systems and other feeder services that will make part of the new bus system will need to build on this experience. Co-ordinating regulation of all the different services will be a relevant challenge, especially since, on the one hand, there is a multiplicity of regulatory agencies in Mexico City: the BRT system is regulated by *Metrobus;* BRS and other new bus services are meant to be regulated by a new institution (the Regulatory Body for Transport, ORT), and three other entities are in charge of the metro, trolley-buses and existing publicly owned buses. On the other hand in the State of Mexico no specialised regulatory agency has been set up for new transport services. In the short-run effective co-ordinated mechanisms should be established through: a) the Committee for the Integrated Public Transport System, which has been created under the New Mobility Law for Mexico City and has been assigned responsibility to co-ordinate planning and regulation of all services operated in Mexico City; and b) the restored Metropolitan Transport Commission or CAMe, to ensure coordinated regulation between services across the ZMVM.

Establishing clear rules for granting concessions and setting and adjusting tariffs is a second challenge. BRT concession terms remain highly discretional. Moving towards concession terms based on a solid methodology built on benchmarking of operating costs to determine cost-recovery rates and necessary subsidies if needed is key. In addition, while social and political contexts can set challenges, moving to an open and competitive tendering process for granting concessions must remain an objective, and a clear schedule for this must be established. During the transition period, authorities can encourage companies formed by incumbent operators to meet similar conditions as those they would encounter in a scenario with open competitive tendering (e.g. setting cost and performance information requirements, and/or introducing quality incentive contracts similar to those used by Transport for London). Also, while not effectively an open competition; authorities could set competitive tendering between existing companies for tendering future corridors, as it is done in Bogotá.

The new system needs to serve origin-destinations adequately. While not meeting high quality, safety and environmental standards, *microbuses* account for a high share of trips and provide services in a huge area of the ZMVM. Any transition to a system with better rationalised routes and higher quality standards must also make sure that origin-destination trips are served and provide alternatives to groups that risk being cut-off from transport services.

Communication strategies

Comprehensive policies for mitigating air pollution involve short term costs for parts of the population that naturally produces opposition. Generating support for traffic restrictions and new charges or taxes is challenging. Designing effective communication strategies to accompany this type of measure is important and can be decisive for effective implementation and sustaining measures introduced rather than reversing policy in response to disapproval.

Surveys conducted in four mid-sized European cities that either introduced congestion charging systems (Stockholm and Gothenburg) or had developed solid plans to do so (Helsinki and Lyon) are instructive in regard to messages that can be central to support for traffic restrictions and demand management measures (Eliasson, 2015). Firstly, effective communication strategies need to address public perceptions from two perspectives present in every individual: 1) the consumer perspective (or self-interest), i.e. direct impacts on time, money, convenience, etc.; and 2) the citizen perspective, or the individuals' view of social issues such as equity, procedural fairness and environmental concerns that are linked (or seen as linked) to a given policy.

Regarding the consumer perspective, a key finding is that the price that an individual will pay as a result of a new policy is very important for determining the support that he/she will give the policy. Nonetheless, the relationship between the price paid and the opposition to the policy is not linear; the greatest shift from a supportive to an opposing attitude occurs between those not paying and those paying something. Beyond this threshold opposition grows more slowly when moving to those groups that will pay the most. Other perceived costs and benefits are also relevant and could in some cases off-set the impact of price in the attitude towards the policy. In the case of congestion charging, time savings appeared to be highly valued. Correctly identifying the costs and benefits of a policy for different groups is therefore important for authorities to pinpoint initial opposition or support. In turn, the strategy for communication must identify and highlight benefits that are highly valued by individuals.

In terms of the citizen's perspective, support or opposition is dependent on attitudes towards the perceived objective of the policy, the rules set by the policy and trust in the government. Messages communicated on the strategy should take on board the following lessons regarding each of these factors (ITF, 2017):

- The perceived objective of the policy: Communication strategies need to ensure that policies implemented with the objective of improving air quality are effectively perceived as such, rather than as measures intended to raise revenues. In particular, if the scheme is seen as a tax it will be closely linked to perceptions of taxes in general and especially where residents think taxes are too high and/or badly used acceptance of the policy will be undermined. To achieve clarity on the objective of congestion charging both London and Stockholm invested heavily in information campaigns to prepare citizens for implementation. In both cases, the introduction of the scheme was discussed as part of a wider long-term plan with clear objectives for air quality improvement.

- The rules set by the policy: Introducing new measures often means introducing new rules, such as restricting access to road space in areas that used to be accessible to all or, as in the case of a congestion charge, introducing a price for the use of the resource. Individuals often initially consider these new rules unfair. Communication strategies can play a crucial role in changing this perception by firstly establishing the need for rationing a resource to achieve the objective and then explaining the advantages of the measure chosen over other mechanisms. Results from the surveys carried out in the four cities showed that individuals had a general tendency to consider introduction of a pricing mechanism to restrict driving access as unfair until faced with the task of recommending a better option (alternatives included queuing, government allocation, and a lottery).

- Trust in the government: Even when the main purpose of implementing traffic restrictions and congestion or environmental charges is not raising revenue, these are not necessarily revenue neutral. Attitudes to the government's trustworthiness in allocating any revenues raised are also a determinant of support or opposition. It is important to make clear that the main objective is not to raise revenues. It is also useful to communicate that any revenues raised will be used in a way that makes sense to the population. Investing this revenue in improving sustainable transport alternatives has shown to be effective for increasing acceptance, both because investing in these modes is seen as positive for attaining air quality objectives and because providing good quality transport alternatives to the car is seen as equitable.

In cases like London and Stockholm improving public transport in step with implementing traffic restrictions helped gain the support of the population. In London bus capacity was increased by 24% on routes affected by the congestion charge. In Stockholm, EUR 170 million were spent on new buses. Stockholm set a seven-month trial period which helped dispel public scepticism, leading to positive support in a referendum for making the charge permanent. In London, the contest for re-election of the Mayor was seen effectively as a referendum on the congestion charge because of its prominence among the policy initiatives taken; the Mayor was re-elected (ITF, 2010).

International experience also shows that to be successful, communication strategies need to create awareness of the health risks of contaminated air and establish a clear relationship between air quality and the measures chosen to cut pollution. Various tools have been developed in London to achieve this and motivate behavioural change. Pollution information alerts are issued the day before high levels of air pollution are forecast, with advice on how to minimise exposure risks. Alert information is displayed on variable message road signs with instructions to switch engines off when stationary to reduce emissions. Alert information is also displayed at bus stops on the signs that indicate waiting time and at the entrances to underground stations. Information on TfL's website provides details of new policies being considered and their estimated impacts well in advance of implementation. Public consultations on prospective measures are a key component. Special communications programmes targeting selected groups have also been undertaken with the aim of creating awareness of particular health risks and responses for avoiding them. For example, campaigns to encourage taxi drivers to avoid idling by deploying people to talk to drivers at taxi ranks.

Paris set up a "citizen jury" consisting of 20 people, representative of a broad range of people, who were provided with detailed information on health issues related to pollution and possible mitigation strategies over four days. The results of this pilot exercise showed that the public was generally poorly informed and that once citizens discovered the impacts of pollution they supported behavioural change and many of the proposed measures: lowering speeds to 30 km/h, a car-free day, public transport investment, expansion of protected bike lanes, implementation of shared electric bikes, expansion of the electric car sharing scheme, shared electric vans for last mile deliveries, education programmes for schools and enforcement on the basis of on-road emissions monitoring. In addition to social networks and the media, Paris also communicates using a large hot air balloon that offers rides to the public in a park in the inner city; the balloon changes colour according to the concentration of pollutants in the air, providing a constant reminder of the purpose of pollution counter-measures.

Figure 1.5. **Paris' Clean Air Balloon**

Note: The balloon takes tourists for rides. The monuments depicted on the balloon change colour with the quality of the air: green in good quality air, passing through yellow and orange to red when air quality is bad.
Source: Ballon de Paris, http://www.ballondeparis.com/fr/ballondeparis/i12-la-couleur and Meet my Paris, http://www.meet-my-paris.fr/visiter-paris-de-maniere-insolite/

Recommendations

Mexico City and the ZMVM have developed stringent air pollution mitigation measures with a fairly comprehensive set of measures similar to policies developed in some cities in other OECD member countries. Radical solutions to pollution from mobile sources, such as large-scale electrification of transport, are expensive and will take time but a series of measures can be taken to strengthen, modify and improve implementation of the air pollution mitigation measures adopted in the metropolis and nationally. The two measures with the most potential in the short term are reducing speeds on trunk roads and reducing the sulphur content of fuel.

Immediate steps

- Implementing traffic management measures that bring vehicle speeds to more constant levels on motorways and ring roads is the most effective approach available to local governments for reducing traffic emissions. Speed limits are an important part of these measures and produce immediate reductions in emissions at very little cost. The 80 km/h speed limit on urban motorways and ring roads introduced in Mexico City in 2015 should be adopted across the ZMVM and enforced to ensure vehicles operate in the 50 to 90 km/h range in which emissions control technologies work best. Limiting speeds to below 80 km/h also helps maintain free flow traffic for longer as congestion builds.

- Improving fuel quality by reducing sulphur content would immediately reduce emissions from all vehicles on the road. Ultra-low sulphur gasoline and diesel are available. International experience suggests that tax differentiation to ensure that the price at the pump of ultra-low sulphur fuels is competitive would produce a shift to 90% clean fuels in the space of one or two years.
- The Federal Environment Ministry has proposed adopting EPA 2010 / Euro VI emissions standards for heavy-duty vehicles for introduction in 2019. A decision has been delayed while the potential value of transitioning through Euro V standards is assessed. Given the very small reductions in emissions achieved in practice on the road by Euro V standards in Europe and the very large improvement achieved with Euro VI standards, the deliberations should conclude rapidly that a transition through Euro V standards would be counterproductive and Euro VI standards should be agreed on without further delay for implementation as early as possible.
- Maintain both on-board diagnostic (OBD) testing of emissions and tailpipe exhaust gas testing under the mandatory vehicle inspection and maintenance programme. Both are required considering their relative advantages. OBD interrogation detects deficiencies, diagnoses faults and helps in avoiding fraud, whilst dynamic tailpipe exhaust testing ensures that emissions are within the current limits and can be used to reject vehicles with illegally altered OBD. Tailpipe emission tests are also an alternative for those vehicles that do not comply with current OBD requirements or do not have OBD. A report on the importance of both tests to achieving the environmental objectives of the law on inspection and maintenance should be prepared to defend the test procedure in court where it has been challenged on constitutional grounds.

Emissions control

National vehicle emissions standards

- Mexico’s proposed national EPA 2010 / Euro VI heavy-duty vehicle emissions standards for new vehicles should be adopted without delay and without transitional arrangements for the much inferior Euro V standards. The crucial change in the Euro standard is a new on-road test for in-service compliance with type-approval regulations, together with a more realistic test cycle and inclusion of cold start conditions in the type approval test.
- EPA Tier 3 / Euro 6 standards for new light-duty vehicles should be adopted nationally as soon as possible and incorporated in incentives under pollution mitigation programs in the ZMVM ahead of national implementation. The US standards are most effective in controlling fugitive VOC emissions; the OBD II requirements under the US standards will also provide for more effective OBD-based inspection and maintenance; the Euro 6 standard includes a particle number limit to control emissions of ultrafine particles from gasoline direct injection engines. In order to assure OBD homologation for all vehicles sold in Mexico, NOM–042-SEMARNAT-2003 should be updated as soon as possible..

Emission control system retrofits

- Continue the bus diesel particulate filter retrofit program with strict certification and testing in use and extend it to other vehicles including garbage trucks. Ensure an appropriate inspection and maintenance program for these retrofit filters to prevent their removal.
- Ensure certification and accreditation for retrofits of three-way catalytic converters, including conversion efficiencies compatible with current emission standards, coverage of durability and free replacement in case of defective performance on inspection.

Off-road mobile sources and special vehicles

- Control non-road mobile machinery emissions, introducing EU regulation 2016/1628.
- Extend incentives for cleaner vehicles, retrofit programs and restrictions on use during pollution alerts to construction equipment and other off-road vehicles.

Non-mobile sources of emissions of volatile organic compounds

- Strengthen measures to control emissions of volatile organic compounds from non-mobile sources because ozone formation in the ZMVM is generally limited by these precursor emissions and mobile sources contribute only a fifth of total emissions.

Incentives for cleaner vehicles

- Incentives for purchase of EPA 2010 / Euro VI heavy-duty vehicles ahead of the new national standards, as already applied for example through the voluntary truck inspection and maintenance program, should be expanded, for example to buses.
- EPA Tier 3 / Euro 6 standards should become reference standards for the vehicle inspection and maintenance certification system, reserving 00 certificates for Tier 3 / Euro 6 light-duty vehicles in the near future, even ahead of their incorporation in national standards.
- Differentiate between 00 and 0 vehicle classes in the restrictions on light-duty vehicle use under pollution alerts. Reserve the 00 class for Tier 3 / Euro 6 light-duty vehicles when this standard is adopted nationally for sales of new models and consider early differentiation ahead of the date the new standard becomes binding once an implementation timetable is agreed.
- Differentiate the vehicle ownership tax (*tenencia*) according to emissions class.

Ultra-low sulphur fuels

- The Federal government should introduce tax incentives for ultra-low sulphur gasoline and diesel as switching to these fuels will produce immediate reductions in emissions from all vehicles on the road.

Inspection and maintenance

- Safeguard and continue to improve the current centralised system for homologation, quality control and conformity of vehicle inspection centres in order to guarantee the reliability of test results. Consider adopting California's best practices including those to guard securely against fraud.

- Continue with the remote surveillance, as well as periodic audits of the equipment used in emissions test centres; use of unmarked control vehicles could also be introduced as an additional check on fraud in licenced concessions.
- Continue to refine how OBD data (such as readiness indicators) are used during the inspection process to improve inspection accuracies and to deter fraud.
- Work to ensure that all inspection jurisdictions within the ZMVM apply best practices for inspection and maintenance so that motorists cannot obtain inspections of lesser stringency depending on where within the region they seek to get their vehicle inspected.
- Incorporate motorcycles into the I&M system and make them subject to vehicle restrictions.

Restricting vehicle use

- The environmental benefits of regular restrictions on vehicle use under the *Hoy No Circula* (HNC) system should be reinforced by measures that incentivise fleet renewal and reduce congestion. In the long term, a combination of such measures might substitute for the HNC system outside of peak pollution episodes.
- There is a case for implementing a low emissions zone that would, at least in a first phase, focus on heavy-duty vehicles including buses and microbuses, using the current vehicle certification and identification systems.
- Light-duty vehicles could also be incorporated into a low emissions zone, with occasional use of more polluting vehicles permitted against payment of an access fee. This would replace access according to number plate. Charges for access to low emission zones should be set to ensure regular users have an incentive to switch to cleaner vehicles and shift to public transport.
- Specific mechanisms to reduce congestion will also be needed. Road pricing and congestion charges are effective tools for this.
- The CAMe should co-ordinate the development of the low emission zones already under consideration by cities in the region to ensure restrictions are based on emissions standards and provide incentives for the cleanest vehicles. The very small scale of the schemes currently under consideration means they will have little impact on air quality in the ZMVM as a whole and larger scale zones are recommended.
- Modifications to restrictions should be supported by analysis of sufficient detail to identify which categories of vehicle traffic generate most pollution and congestion and the levels of charges needed to incentivise fleet renewal and modal shift. Ex-post evaluation of the performance of restrictions is also important for modifying schemes and implementing complementary policies as conditions change.

Enforcement

- Use the Regional Environment Commission as a forum to negotiate reciprocal arrangements between the States in the CAMe region for the payment of fines for contravening inspection and maintenance regulations and restrictions on the use of vehicles.

Traffic management

Parking

- Extend the Ecoparq on-street parking controls to other parts of Mexico City and to other areas in the ZMVM.
- Differentiate parking charges according to demand and availability of public transport services.
- Abolish minimum requirements for off-street parking in building codes.

Speed limits

- The speed limits differentiated by road type introduced for road safety in Mexico City in 2015 should be extended across the whole of the ZMVM as in addition to cutting road trauma they tend to result in smoother traffic flow, lowered excess emissions generated in stop-go traffic, excess acceleration and excess speed.

Enhancing sustainable transport alternatives

- Renew efforts to develop a framework for metropolitan governance of transport in the ZMVM and carry out strategic planning of public transport as set out in the 2014 PROAIRE program.
  - In the short run restore the Metropolitan Commission for Transport or assign its responsibilities to CAMe, making sure adequate financial resources and permanent staff for carrying out these responsibilities are also made available to any of these institutions.
  - Authorities should also work in adjusting the legal and institutional frameworks for establishing a metropolitan transport authority for the ZMVM in the longer term.
- Metropolitan governance should focus on:
  - Harmonising the legal framework across the ZMVM, particularly to make explicit priorities for investing and allocating road space in favour of public and non-motorised modes.
  - Integrating transport services across jurisdictions.
  - Developing a Mobility Master Plan for the ZMVM and linking funding allocation to priorities set by the plan.
- Improve linkages between land-use and transport planning. Implement the property development Mobility Assessment procedure provided under Mexico City's 2015 Mobility Law and link it directly to the process of awarding construction authorisations. Expand this framework across the ZMVM.
- Continue to invest in improving the quality of public transport services, including access to metro and rail stations, BRT platforms and bus stations, and continue to invest in infrastructure for safe cycling and walking. Viable alternatives are essential to the success of restrictions on the use of cars. To enhance the financial capacity for this investment:
  - Move to more sustainable models for public transport tariff systems, making fare adjustments on a regular, planned basis with more modest increases rather than large, sporadic hikes, and replace generalised subsidies with subsidies targeted to low income and

vulnerable users. Tariffs and subsidies should be set based on solid evaluations of operating costs and affordability of the population.

  - Earmark revenues from charges for the use of private vehicles, including fines for failure to comply with the No-driving day and inspection and maintenance systems and any future traffic restriction schemes, and also the vehicle ownership tax, to investment in public transport and walking and cycling facilities.
  - Make use of land-value capture mechanisms, such as the existing betterment charge (*Contribución de mejoras*) for investment in public transport.

- Accelerate bus reform throughout the ZMVM and where agreements are made to scrap microbuses and operate routes under consolidated concessions with higher standard vehicles, ensure the old vehicles are actually scrapped and do not continue to be used in competition with the new services.

Air quality management plans

- The Federal government should establish air quality monitoring systems and management plans for areas in Mexico beyond the ZMVM that do not meet national ambient air quality standards.

Communication

- Run campaigns to raise awareness of the health risks of contaminated air, the steps individuals can take to reduce air pollution, and the investments made by government to provide alternatives to the use of polluting vehicles, including public transport.
- Invest in information campaigns to prepare citizens for modifications to pollution mitigation policies, stressing the air quality and health benefits targeted. Once revenues are earmarked to flanking measures such as investment in public transport, this should also be stressed.
- Subject policy proposals to public consultation.
- Report regularly on the achievements of the policies adopted.

These recommendations, although not exhaustive, cover the broad range of measures that should be taken. Table 1.8 maps the different measures according to the broader policy category to which they belong, as well as the time frame for implementation. For the purpose of the table, short, medium and long term correspond to the periods of 1-3 years, 3-5 years and 5-10 years respectively. Whilst this report does not attempt cost benefit analysis or a regulatory impact assessment of the measures, a rough idea of their potential, relative costs and the timeframe over which they yield benefits, as well as particular challenges and additional steps needed is also provided in Table 1.9.

Table 1.8. **Map of recommended measures and time frame for implementation**

Short term (1-3 years)	Medium term (3-5 years)	Long term (5-10 years)
Emissions control		
Adopt national HDV Euro VI standard. **Adopt national LDV EPA Tier 3/Euro 6 standard.** **Develop an I&M for Bus DPF Retrofit.** **Certification and accreditation for LD retrofits (three-way cc).** **Extend incentives for cleaner technologies and restrictions on use during pollution alerts to construction and off-road sources.** **Negotiate tighter VOC standards for non-mobile sources.**	Implement national HDV Euro VI standard. Implement national LDV EPA Tier 3/Euro 6 standard. Introduce EU regulation 2016/1628 for non-road mobile machinery emissions.	
Incentives for clean vehicles		
Incentives for purchase of Euro VI /EPA 2010 buses. **EPA Tier 3 / Euro 6 standards reference for "00" category in I&M and differentiate between "00" and "0" classes in restrictions on vehicle use under pollution alerts.**	Differentiate vehicle ownership tax according to emission class.	
Fuel quality		
Introduce tax incentives for ultra-low sulphur gasoline and diesel.		
I&M		
Introduce periodic audit and use of unmarked control vehicles. **Incorporate motorcycles.** **Maintain primary reliance on OBD testing and develop support to defend this in court.**	Introduce test result centralisation into the I&M system.	

Table 1.8. **Map of recommended measures and time frame for implementation (continued)**

Short term (1-3 years)	Medium term (3-5 years)	Long term (5-10 years)
Vehicle use restrictions		
	Implement LEZ for HDV including buses and microbuses.	Incorporate LDVs and motorcycles to the LEZ in combination with road pricing/congestion charges. Use HNC restrictions for pollution episodes only.
General Traffic Management		
Expand speed limits to the whole of the ZMVM. **Extend Ecoparq on-street parking controls to the whole of the ZMVM.**	Abolish minimum requirements for off-street parking in building codes. Set differentiated parking charges.	
Enforcement		
Use CAMe to negotiate reciprocal arrangement for the payment of fines for contravening I&M regulations, restrictions on the use of vehicles, and other traffic regulations.		
Air quality plans		
	Establish air quality monitoring beyond the ZMVM and require management plans for areas that do not meet national ambient air quality standards.	

Table 1.8. **Map of recommended measures and time frame for implementation (continued)**

Short term (1-3 years)	Medium term (3-5 years)	Long term (5-10 years)
Enhancing and promoting sustainable transport modes		
Restore COMETRAVI or assign its responsibilities to CAMe (with adequate staff and financial resources). **Work on harmonising legal frameworks, integrating transport services across jurisdictions and in developing a Mobility Master Plan for the ZMVM.**	Make the necessary adjustments in the national legal framework to allow establishing Metropolitan Transport Authorities.	Establish a Metropolitan Transport Authority for the ZMVM.
Implement the property development Mobility Assessment (in Mexico City's 2015 Law) and link it to the process of awarding construction authorisations; expand across the ZMVM. **Move towards public transport tariffs with regular and planned fare adjustments.** **Develop solid methodologies for calculating costs and affordability and determine the need for subsidies accordingly.**	Replace generalized subsidies with subsidies targeted to low income and vulnerable users.	
Earmark revenues from private vehicle charges (including fines for non-compliance with I&M and HNC) to investment in public and active modes. **Make use of betterment charges for public transport investments.** **Accelerate bus reform and ensure microbuses replaced are effectively scrapped.**	Explore use of other land value capture mechanisms for investing in public transport and active modes.	

Table 1.9. **Summary of recommended measures and responsible authorities**

	Measure	Decision and implementation time frame	Responsible authorities	Challenges and additional steps
Emissions control	National HDV EPA2010 / Euro VI standard	Short	SEMARNAT	
	National LDV EPA Tier3 / Euro 6 standard	Short	SEMARNAT	Negotiation with car industry
	Restrictions on non-road machinery during alerts	Short	CAMe/States	Negotiation with construction industry
	I&M for Bus Retrofits	Short	States	Negotiation with concessionaires
	Certification and accreditation for retrofits - LDVs	Short	States	Quality assurance
	Non-road mobile machinery emissions standards 2016/1628/EU	Medium	SEMARNAT	Negotiation with construction and vehicle industry
	Tighter control of non-mobile VOC sources	Short	CAMe	Negotiation with a range of businesses
Incentives for cleaner vehicles	Euro VI/EPA 2010 bus incentives	Short	States	Negotiation with bus concessionaires
	I&M class revision	Short	CAMe	Communication with public
	I&M 00-0 class differentiation	Short	CAMe	Communication with public
	Vehicle ownership tax differentiation	Short	States	Communication with public, fiscal neutrality or earmarking
Fuel quality	ULS fuels	Short	SEMARNAT	Achieving fiscal neutrality
I&M	I&M audit and checking	Short	CAMe/States	Introduce in conjunction with the renewal of concessionaires for I&M testing
	Incorporate motorcycles into I&M and vehicle restrictions	Short	CAMe/States	Communication with the public
	I&M test result centralisation	Medium	CAMe	Negotiation with I&M concessionaires

Table 1.9. **Summary of recommended measures and responsible authorities (continued)**

	Measure	Decision and implementation time frame	Responsible authorities	Challenges and additional steps
Restrictions on vehicle use	Wide scale LEZ for HDVs	Medium	States/CAMe	Effective communication with public. Design based on detailed analysis of restrictions/charges on fleet renewal and ultimately on pollution. Consideration of possible economic negative effects and action to mitigate them.
	Wide scale LEZ for all vehicles with HNC restrictions used for pollution episodes only	Long	CAMe	Effective communication with public. Design based on detailed analysis of restrictions/charges on fleet renewal, modal shift and pollution. Consideration of possible socio-economic negative effects and plan for actions to mitigate them.
	Road pricing/congestion charge	Long	States	Design based on detailed analysis for estimated effects of charges on travel behaviour and modal shift, and ultimately on congestion. Consideration of possible socio-economic negative effects and plan for actions to mitigate them.
General traffic management	Speed limits	Short	States	Effective communication with public.
	Ecoparq extension	Short	States	Effective communication with public. Co-ordination between land-use and transport authorities.

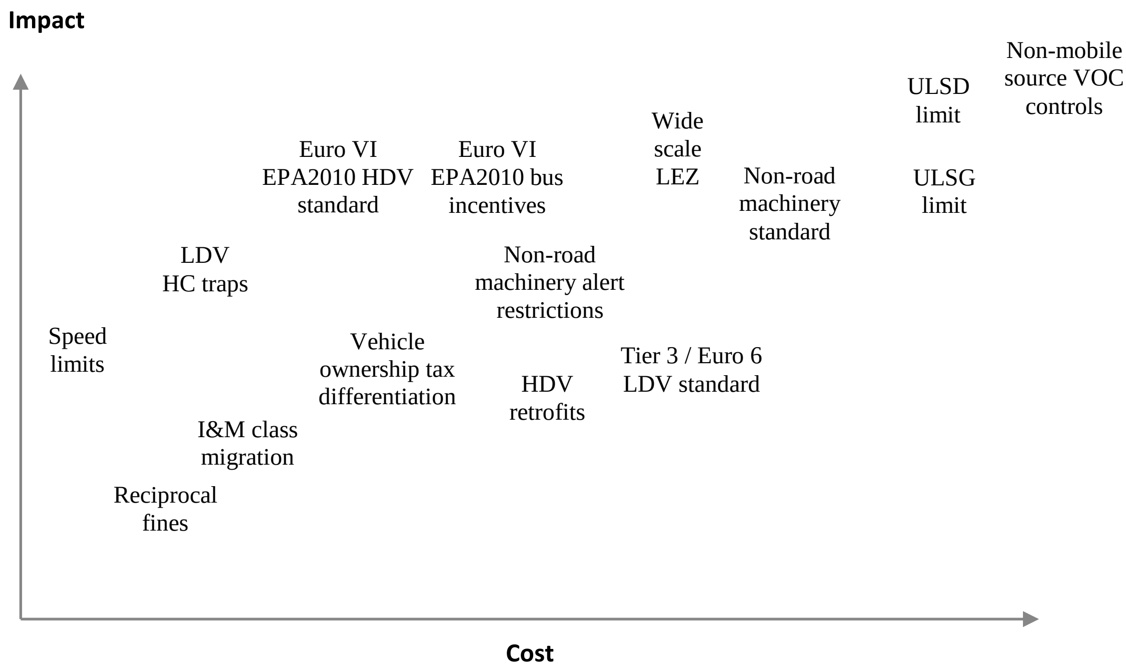
Table 1.9. **Summary of recommended measures and responsible authorities (continued)**

	Measure	Decision and implementation time frame	Responsible authorities	Challenges and additional steps
General traffic management (continued)	Differentiated parking charges	Medium	States	Effective communication with public. Co-ordination between land-use and transport authorities. Removal of legal barriers.
	End minimum parking requirements in building code	Medium	States	Effective communication with public. Co-ordination between authorities in charge of land-use and transport.
Enforcement	Reciprocal enforcement of fines	Short	States/CAMe	Communication with the public.
Air quality plans	National air quality monitoring and requirements for management plans for areas that do not meet national air quality standards	Short	SEMARNAT and States	Negotiation with the States
Enhance and promote sustainable transport modes	Restore Metropolitan Commission for Transport or assign its responsibilities to CAMe	Short	Federal Government and States in the ZMVM	Agreement of States to allocate adequate resources and assign dedicated staff.
	Develop the Mobility Master Plan for the ZMVM	Medium	States plus Metropolitan Commission in charge	Data collection and improving analysis tools. Co-ordination with Territorial Plan (POZMVM). Link fund allocation (federal and State funds) to priorities set by the Master Plan.
	Operational and financial integration between transport modes and across State boundaries in the ZMVM	Medium	States plus Metropolitan Commission in charge	
	Property development mobility assessment procedure	Long	States (land-use and transport authorities), Metropolitan Commission	Communication with property developers.
	Introduce tariff systems with regular and planned fare adjustments	Short	States	Communication with public.

Table 1.9. **Summary of recommended measures and responsible authorities (continued)**

	Measure	Decision and implementation time frame	Responsible authorities	Challenges and additional steps
Enhance and promote sustainable transport modes (continued)	Shift from generalised to targeted subsidies	Medium	States	Develop framework for analysis on affordability (could build on Prospera programme) and linking smartcards to award of subsidies.
	Earmark charge and fine revenues to public transport	Short	States	Negotiation with fiscal authorities.
	Betterment charges for sustainable transport investment	Short	States	Communication with property developers.
	Explore other land value capture mechanisms	Medium	Federal Government and States	
	Establish a Metropolitan Transport Authority for the ZMVM	Long	Federal Government and States	Adjust legal and institutional framework for allowing establishment of metropolitan transport authorities.
	Accelerate bus reform and make sure microbuses are effectively replaced and scrapped	Short	States	Negotiation with bus concessionaires

Figure 1.6. **Broad indication of relative impact and cost of selected measures**



2. Air pollution and mitigation measures in Mexico City today

Introduction: The current situation and the high ozone concentration episodes of 2016

The World Health Organization (WHO) estimates that in 2012, air pollution in Mexico caused 17 000 premature deaths (WHO, 2016). In Mexico City (just the central part of the metropolitan area), it is estimated that if the WHO recommendations on air quality were observed, more than 1 400 of these deaths could be avoided each year (INECC, 2016b). A series of measures have been taken to address this serious public health problem, which has considerably reduced pollutant concentrations in comparison to those observed in the mid-80s and the beginning of the 90s. However, despite the improvements observed in lead, carbon monoxide (CO), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) concentrations, air quality standards for ozone and for PM_{10} and $PM_{2.5}$ particulates have not been met, and air pollution is still a challenge for both authorities and inhabitants.

Geographic and institutional context

The Metropolitan Area of Valle de México (ZMVM) is situated in the central area of the country in a basin with an altitude of between 2 200 and 2 800 metres above sea level, and surrounded by mountain elevations that reach above 5 000 metres (INEGI, 2014). This situation contributes to the generation of high pollutant concentrations. The altitude reduces the efficiency of combustion processes, the relief makes the dispersion of pollutants difficult and the intensity of solar radiation fosters the formation of ozone and other secondary pollutants.

Box 2.1. **Metropolitan Area of the Valle de Mexico**

- 20.1 million inhabitants
- Motorisation index: 250 vehicles per 1 000 inhabitants in 2014
- 5.3 million vehicles: 80% private (cars, SUVs, motorcycles), 13% freight, 7% public transportation
- Energy consumption: 543 PJ directly from oil products, of which over 50% are transport fuels
- 2 410 regulated trades and services
- 1 935 regulated industries (from a total of 5 200)
- 5 fuel storage depots
- 5.8 million residences

Source: Secretariat of Environment of Mexico City (SEDEMA) (2016).

Administratively speaking, the ZMVM comprises three jurisdictional entities: Mexico City (16 territorial delegations), part of the State of Mexico (59 of its 125 municipalities) and part of the State of Hidalgo (one municipality). The State of Mexico's municipalities cover the greatest territorial proportion (6 000 km2 vs. 1 500 km^2 occupied by Mexico City) and population (12.2 vs. 8.8 million inhabitants) (SEDEMA, 2016a). This administrative division implies that strategies to combat pollution must involve authorities from all three States as well as representatives from the municipalities. As some pollution sources are regulated by federal agencies, including Federal Environmental authorities is also essential.

Co-ordination among these authorities began in 1990 with the Comprehensive Programme against Atmospheric Pollution (*Programa Integral contra la Contaminación Atmosférica*, PICCA). The programme included an air quality assessment and review of emission sources, commitments made in order to reduce pollution (such as the introduction of catalytic converters) and a calculation of the cost of these commitments. Two years later, preparations began for a commission to co-ordinate the institutions at all government levels to combat pollution. Finally, in 1994, the Metropolitan Environmental Commission (*Comisión Ambiental Metropolitana*, CAM) was created. The commission included all 16 territorial delegations of Mexico City (then a Federal District), 18 municipalities from the State of Mexico, and the former Secretariat for the Environment, Natural Resources and Fishing (*Secretaría de Medio Ambiente, Recursos Naturales*, SEMARNAT) in the Federal government.

The CAM was responsible for co-ordinating actions for improving air quality for almost 20 years, as well as issuing the Air Quality Improvement Programmes (*Programas para Mejorar la Calidad del Aire*, PROAIRE) for the ZMVM. In 2013 it became the Environmental Commission for the Megalopolis (*Comisión Ambiental de la Megalópolis*, CAMe). It now includes, in addition to the 16 delegations (boroughs) of Mexico City, every municipality within the states of Hidalgo, Mexico, Morelos, Puebla and Tlaxcala, since they either have an impact on or are affected by the air quality of the ZMVM. The commission is in charge of developing the Environmental Alert Programmes to address high pollutant concentration episodes and co-ordination between State and Federal authorities to design and enforce emission control programmes.

Box 2.2. **Atmospheric Monitoring System (*Sistema de Monitoreo Atmosférico* - SIMAT)**

The ZMVM has over 40 monitoring and meteorological stations distributed between four sub-systems:

- Atmospheric Monitoring Automatic Network (*Red Automática de Monitoreo Atmosférico* - RAMA): Started operation in 1986. It currently has 29 monitoring stations with continuous devices to measure SO2, CO, NO_2, ozone, PM_{10} and $PM_{2.5}$, as well as a maintenance and calibration laboratory for its equipment.
- Atmospheric Monitoring Manual Network (*Red Manual de Monitoreo Atmosférico* - REDMA): 11 monitoring sites with manually operated equipment for particle sampling (carried out every six days).
- Meteorology and Solar Radiation Network (*Red de Meteorología y Radiación Solar* - REDMET): 19 sites with continuous surface meteorological variable measuring equipment for temperature, relative humidity, wind direction and velocity, solar radiation and atmospheric pressure.
- Atmospheric Deposit Network (*Red de Depósito Atmosférico* - REDDA): 16 sampling sites with semi-automatic equipment used to collect dry and humid deposit samples every seven days.

The Atmospheric Monitoring System (SIMAT) is supported by the Environmental Analysis Laboratory (*Laboratorio de Análisis Ambiental* - LAA), formed by laboratories that perform elemental analyses, gas chromatography, gravimetric and aerosol studies for the samples that each network collects. The Air Quality Information Centre (*Centro de Información de la Calidad del Aire* - CICA) stores, validates, processes and issues data generated by the monitoring programs.

Source: SEDEMA (http://www.aire.cdmx.gob.mx/default.php?opc='ZaBhnmI=').

Every action under these programmes is based on the air quality assessment carried out by the Atmospheric Monitoring System for Mexico City (*Sistema de Monitoreo Atmosférico de la Ciudad de México*, SIMAT). This system has continuously recorded pollutant concentrations within the Mexico City Valley area since the late 1980s working with over 40 monitoring stations distributed around the metropolitan area of Mexico City (Box 2.2). These measurements are recorded, processed and communicated through yearly reports, on websites on an hourly basis, through mass media and, recently, through a smartphone application.[8] When SIMAT records concentrations that exceed the thresholds established by the PCAA, it notifies the CAMe in order to activate the corresponding measures. The Secretariat for the Environment of Mexico City's Government administers the SIMAT and its component systems, including monitoring stations located in the State of Mexico (SEDEMA SIMAT, n.d.).

Box 2.3. **Websites for information on air quality and pollution counter-measures**

PROAIRE

- Air pollution monitoring: http://www.aire.cdmx.gob.mx/default.php?opc=Z6BhnmI=&dc=aA==
- Current air quality: http://www.aire.cdmx.gob.mx/default.php?opc=%27YqBhnmI=%27

CAMe

- Air pollution counter-measures: http://www.gob.mx/comisionambiental

Air quality standards and trends

The Air Quality Index (*Índice de Calidad del Aire*, formerly known as IMECA) is used to communicate air quality conditions to citizens. It is calculated based on monitoring station measurements of atmospheric concentrations through an algorithm defined by a local regulation (NADF-009-AIRE-2006). The 100-point value corresponds to the acute exposure limit defined under health protection regulations.

Table 2.1. **Air Quality Index breakpoints in Mexico and the US**

AQI	**Air quality category**		**O_3** (ppb 8-hour)		**O_3** (ppb 1-hour)		**PM_{10}** ($\mu g/m^3$ 24-hour)		**$PM_{2.5}$** ($\mu g/m^3$ 24-hour)	
	MX	US	MX	US	MX	US	MX	US	MX	US
0 – 50	**Buena**	**Good**		0 54	0 70		0 40	0 54	0 12	0 12
51 – 100	**Regular**	**Moderate**		55 70	71 95		41 75	55 154	12.1 45	12.1 35.4
101 – 150	**Mala**	**Unhealthy Sensitive Groups**		71 85	96 154	125 164	76 214	155 254	45.1 97.4	35.5 55.4
151 – 200	**Muy Mala**	**Unhealthy**		86 105	155 204	165 204	215 354	255 354	97.5 150.4	55.5 150.4
201 – 300	**Extrema-damente Mala**	**Very Unhealthy**		106 200	205 404	205 404	355 424	355 424	150.5 250.4	150.5 250.4
301 – 400		**Hazardous**			405 504	405 504	425 504	425 504	250.5 350.4	250.5 350.4
401 – 500					505 604	505 604	505 604	505 604	350.5 500.4	350.5 500.4

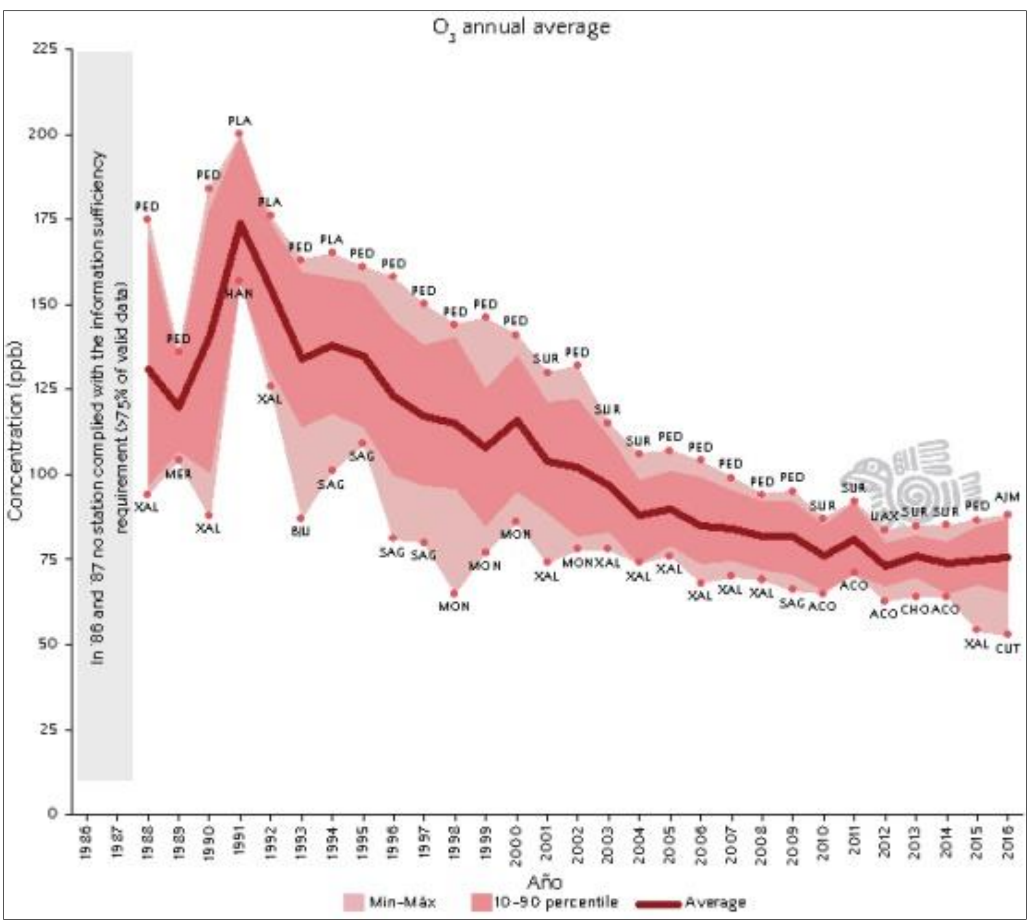
Sources: SEDEMA, http://www.aire.cdmx.gob.mx/default.php?opc=%27ZaBhnmI=&dc=%27aQ==; US Electronic Code of Federal Regulations, Part 58, Ambient Air Quality Surveillance, http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&r=PART&n=40y6.0.1.1.6#sp40.6.58.f

The index adopts the methodology developed by the US EPA, with an identical categorisation of the Air Quality Index (AQI) but locally determined breakpoints for each pollutant. These were last updated in Mexico for ozone, PM_{10} and $PM_{2.5}$ in 2014 (under NOM-020-SSA1-2014 and NOM-025-SSA1-2014). Current breakpoints for these pollutants are summarised in Table 2.1.

Although the concentration levels for most atmospheric pollutants in Mexico City are below the acute exposure limits set by health regulations, ozone and particulates concentrations still regularly exceed national air quality regulations. Figure 2.1 shows concentration trends for ozone since 1986.

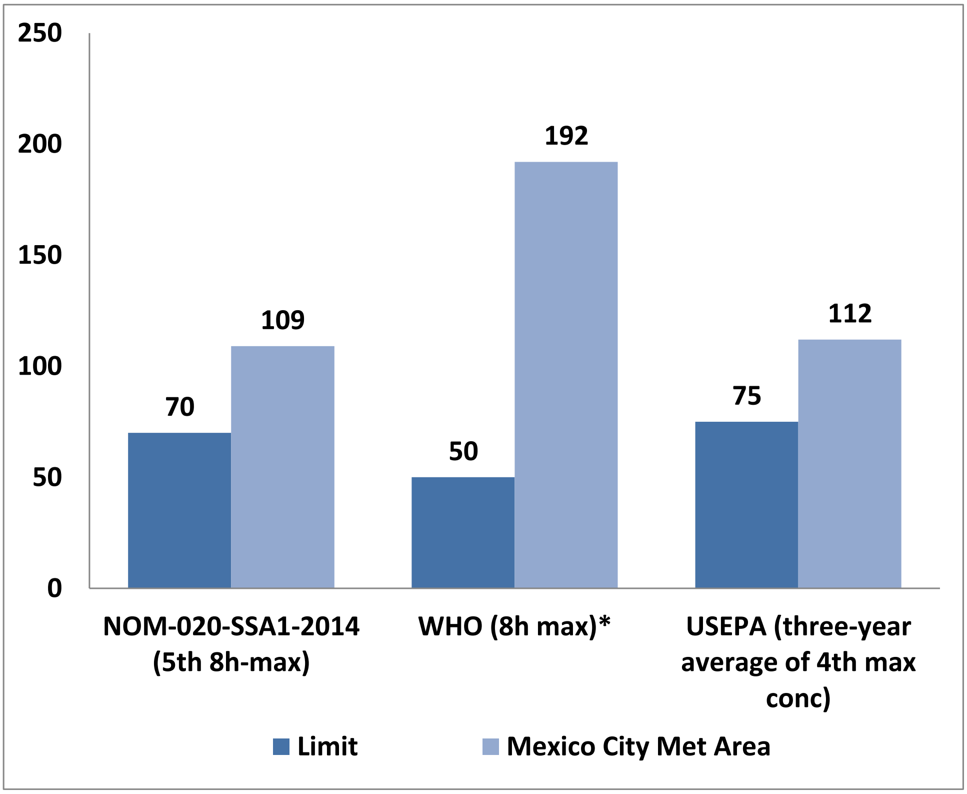
The improvement for this pollutant since 1992 is remarkable. However, as noted in the latest, 2014, report on air quality for Mexico City ozone concentrations do not comply with regulated Mexican limits for chronic and acute exposure (SEDEMA, 2015). Figure 2.1 also shows a slight increase in concentrations since 2014. Figure 2.2 shows concentrations recorded within the metropolitan area compared to limits prescribed by the Ministry of Health to protect public health, as well as those set by the World Health Organization (WHO) and the United States' Environmental Protection Agency (USEPA).

Figure 2.1. **Trends in ozone concentrations, annual average (1986-2016)**



Source: SEDEMA, SIMAT.

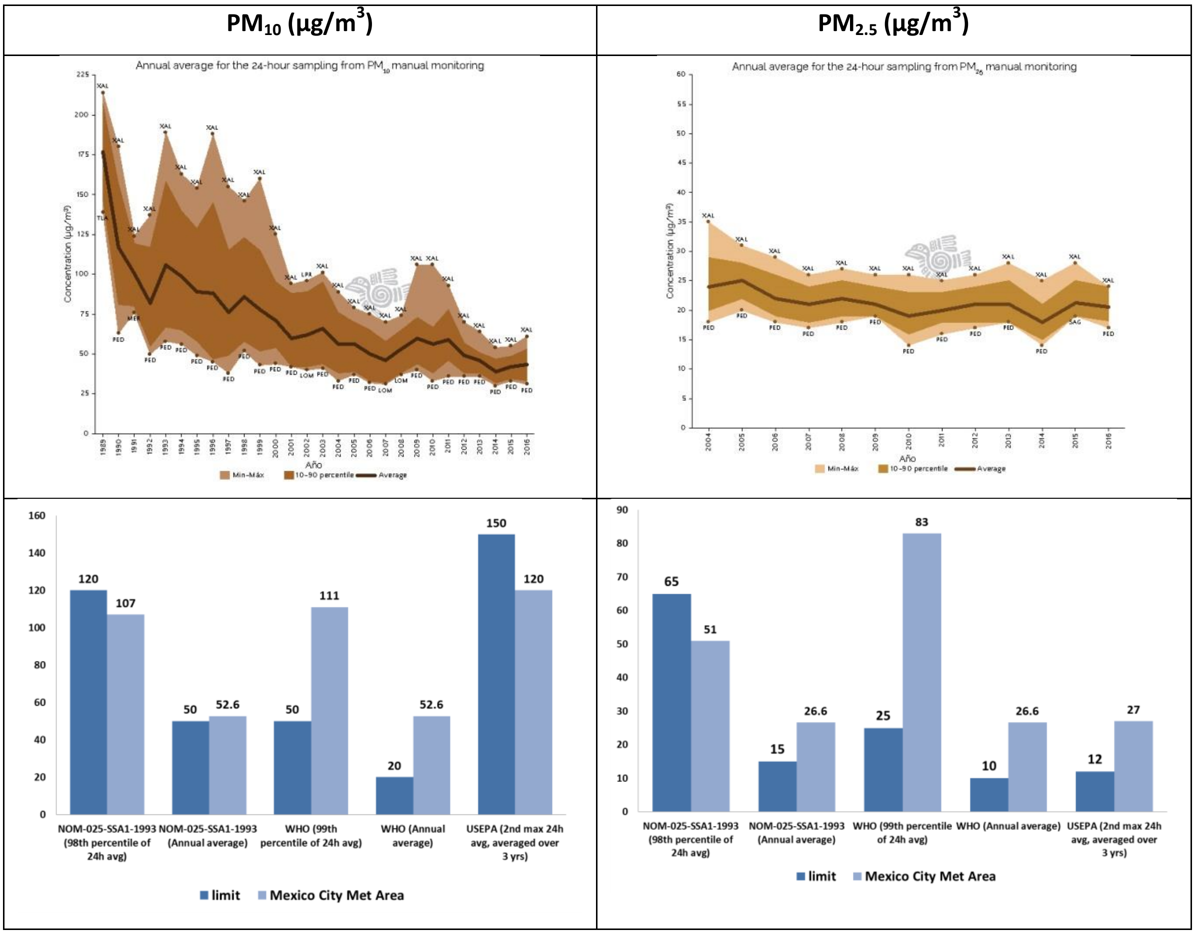
Figure 2.2. **Ozone concentrations vs. Mexican, WHO, and US air quality limits. Ozone (ppb), WHO recommendation = 100 µg/m^3**



Source: SEDEMA.

Although most recent acute pollution episodes in Mexico City are related to high ozone concentrations, air quality concerning particulate matter is also troubling. The 2014 SIMAT report indicates that PM_{10} concentrations have decreased since 1992, but they still do not comply with Mexican health protection regulations. $PM_{2.5}$ concentrations have remained practically at the same level since they started being measured in 2004. Figure 2.3 shows trends for particulate matter concentrations and compares them against health protection limits. It should be noted that $PM_{2.5}$ and PM_{10} exceed chronic exposure limits under Mexican and WHO standards.

Figure 2.3. **Annual average concentration tendencies for PM10 y PM2.5, and compliance with Mexican, WHO and US regulation suggestions**



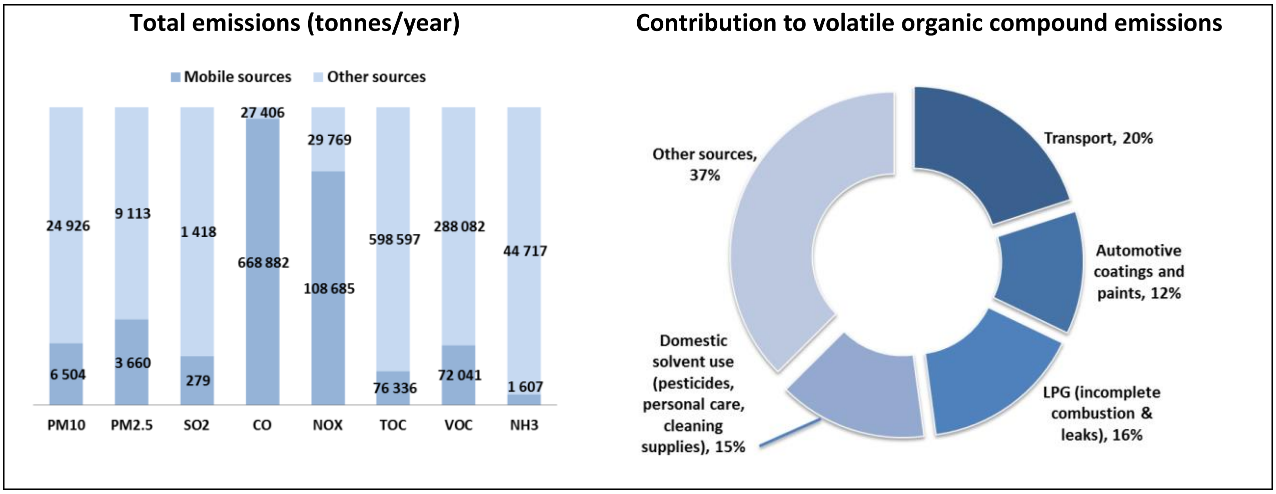
Source: SEDEMA (2015).

Main pollution sources

Since ozone is a secondary pollutant, reducing its atmospheric concentration is a complex challenge. Pollution counter-measures need to be based on an analysis of the sources of emission of precursor gasses (nitrogen oxides and volatile organic compounds) as well as the geographic and meteorological conditions that promote its formation. Figure 2.4 summarises the emission sources for local pollutants included in the most recent emissions inventory for Mexico City (2014). As can be seen, the main sources of emissions of nitrogen oxides (NOx) are motor vehicles, contributing 80% of the emissions. According to assessments from the Ministry of Environment for Mexico City, about 5.3 million vehicles circulate in the Metropolitan Area of Valle de México, of which 80% are gasoline fuelled private cars, SUVs and motorcycles, 13% are heavy-duty freight vehicles, mostly using diesel, and 7% are public transportation vehicles (mostly diesel).

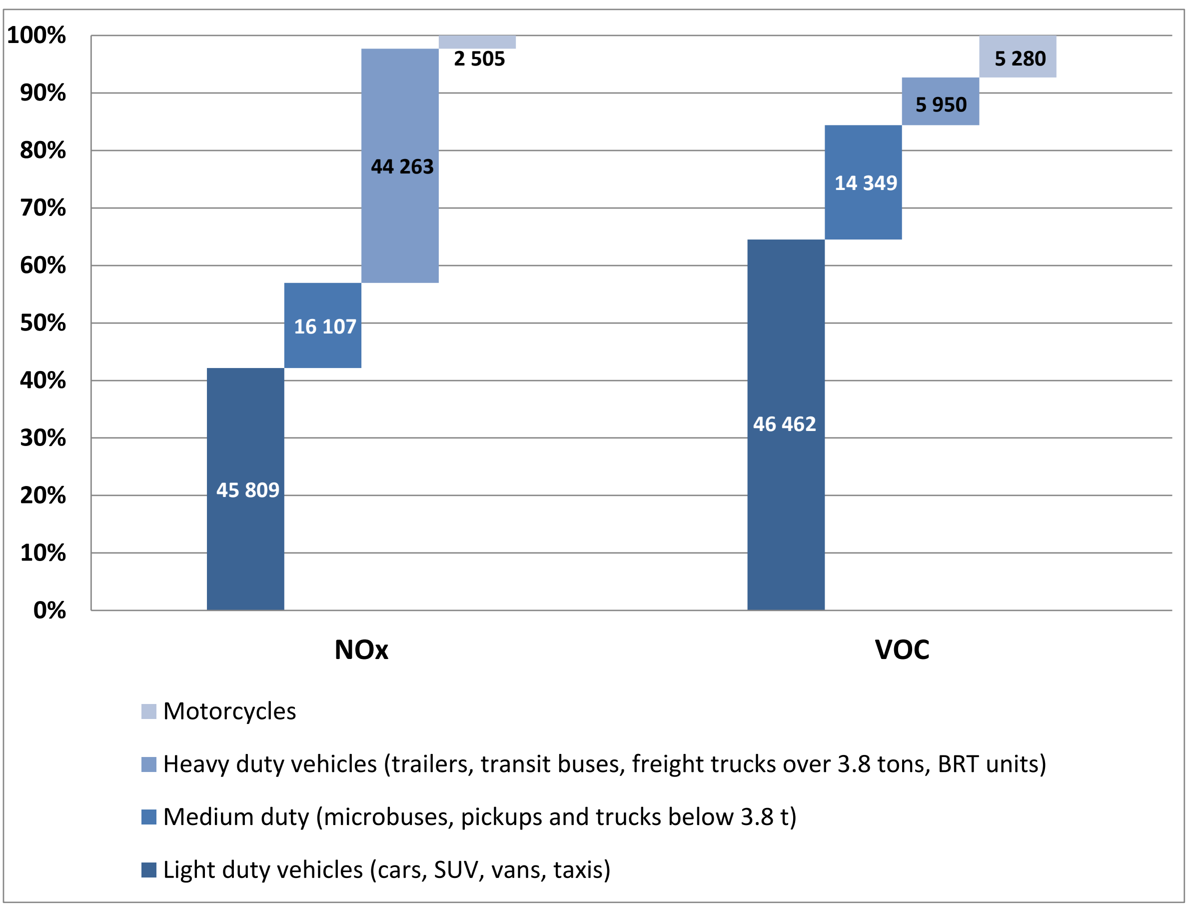
Most light-duty vehicles run on gasoline and are relatively new; 70% are between 0 and 10 years old. These, as described in Chapter 3, comply with NOx and hydrocarbon emission limits, corresponding to the more relaxed US Tier 2 standard limits (*bins* 7-10) and, for European manufacturers, Euro 3 emissions standards.

Figure 2.4. **Atmospheric pollutant emissions in the ZMVM (2014)**



Source: SEDEMA (2016a).

Figure 2.5. **Ozone precursor emissions from mobile sources (tonnes/year)**



Source: SEDEMA (2016a).

Figure 2.5 shows the total emissions of precursors for ozone formation from mobile sources. As can be seen, the contributions of light and heavy-duty vehicles to NOx emissions are roughly the same.

Whilst light-duty vehicles contribute most of the VOC emissions from mobile sources, other sources contribute more to overall emissions (Figure 2.6). Combustion of liquefied petroleum gas releases significant quantities of un-burnt propane and butane, mostly from residential heating (which constitutes 65% of the total consumption for this fuel). In addition, 8.6 million tonnes of solid waste is generated every year in the city, which produce about 280 thousand tonnes of methane (SEDEMA, 2016a). The contribution from these sources is especially important for ozone formation in the Mexico City metropolitan area, since the scientific evidence collected on several field assessments carried out in 2006 showed that the formation of ozone in the city is very sensitive to VOC concentrations (INECC, 2016a).

High ozone pollution events

The ozone pollution season in Mexico City's metropolitan area usually begins in late February and ends in June. During these months, high solar radiation, longer daylight hours, atmospheric stability and low humidity contribute to ozone formation and accumulation. Historically this is the period during which the highest ozone levels have been registered, activating ozone alerts. Figures 2.6 and 2.7 illustrate the way peak pollution levels have declined; Figure 2.6 presents a series of maps showing the highest ozone concentrations recorded in 1995, 2000, 2005, 2010, 2015 and 2016, using the current air quality index. As it can be seen, although high levels of ozone continue to be experienced, the peak levels have decreased over time in response to pollution mitigation measures.

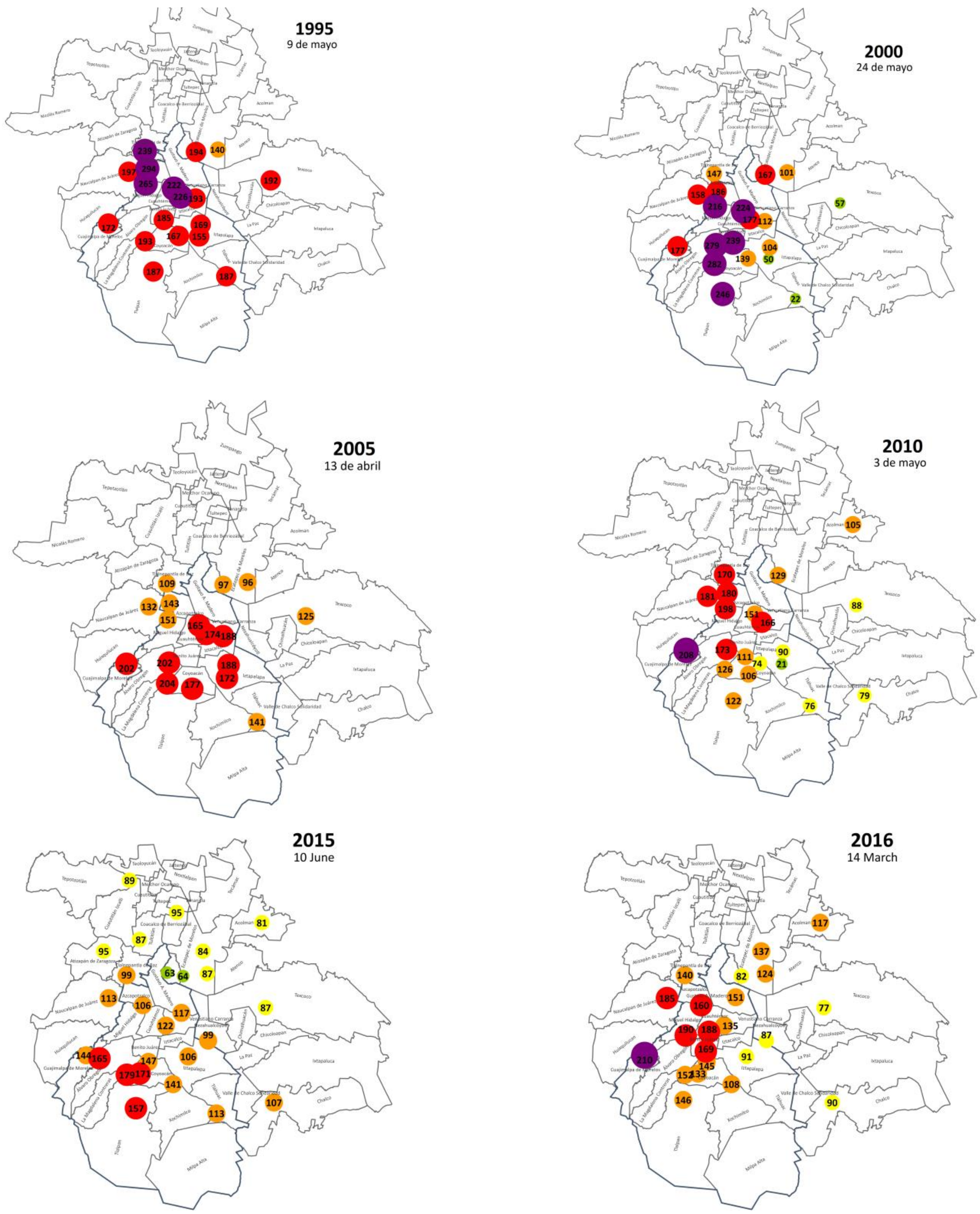
The ozone concentration at which the Atmospheric Environment Alert Program (*Programa de Contingencias Ambientales Atmosférica*s, PCAA) is activated has changed over time, as Table 2.2 records. The latest modification to the PCAA included eliminating the warning, pre-alert, stage and reducing the alert activation threshold (from 180 points/185 ppb to 150 points/155 ppb).

Table 2.2. **Modifications to the Atmospheric Environment Alert Program**

	Activation thresholds Points on the Air Quality Index (IMECA)		Ozone limit Concentrations equivalent to 151 IMECA points
	Pre-alert	**Alert Phase 1**	1-hour average
2005	200	240	250 ppb
August 2012	200	240	250 ppb
October 2014	151	181	185 ppb
April 2016	Eliminated	151	155 ppb

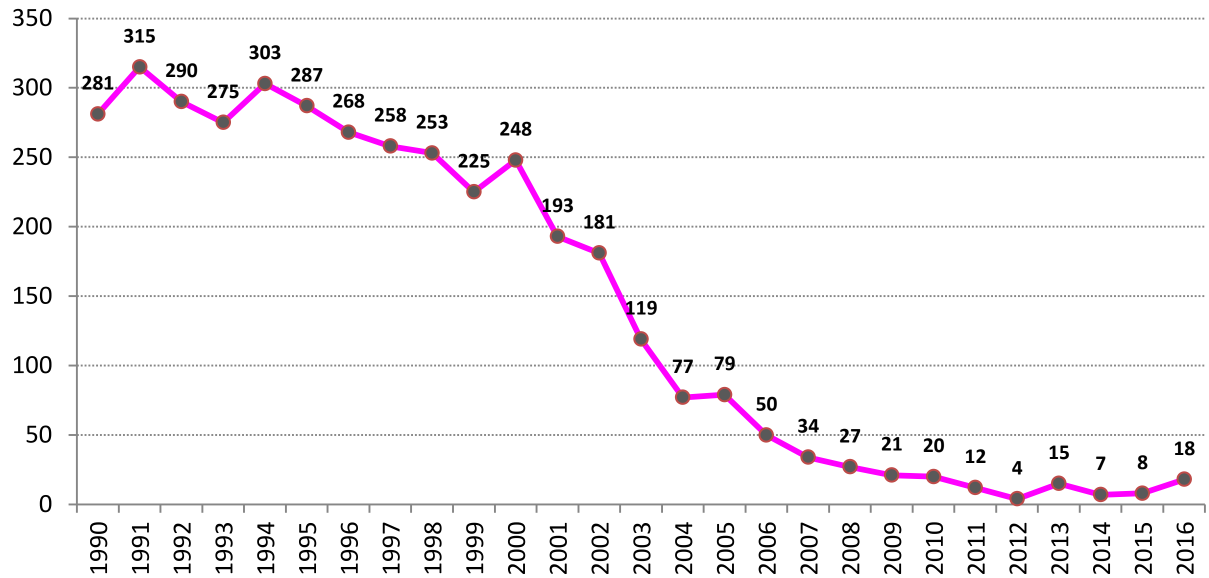
Source: SEDEMA, http://www.aire.cdmx.gob.mx/descargas/ultima-hora/calidad-aire/pcaa/pcaa-modificaciones.pdf

Figure 2.6. **High ozone events over time**



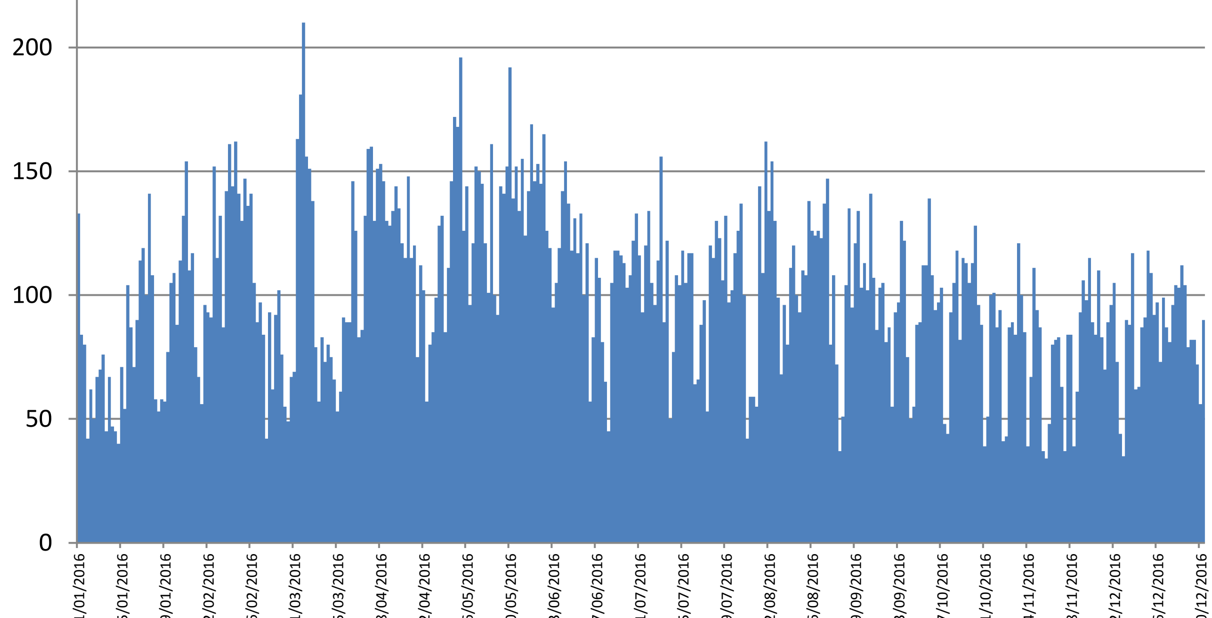
Note: the number inside the circles represents the ozone hourly concentration in ppb.
Source: SEDEMA SIMAT (2016).

Figure 2.7. **Number of days on which maximum hourly ozone concentration exceeded 155 ppb (150 points on the IMECA air quality index today)**



Source: SEDEMA.

Figure 2.8. **Daily Air Quality Index during Ozone season in 2016**



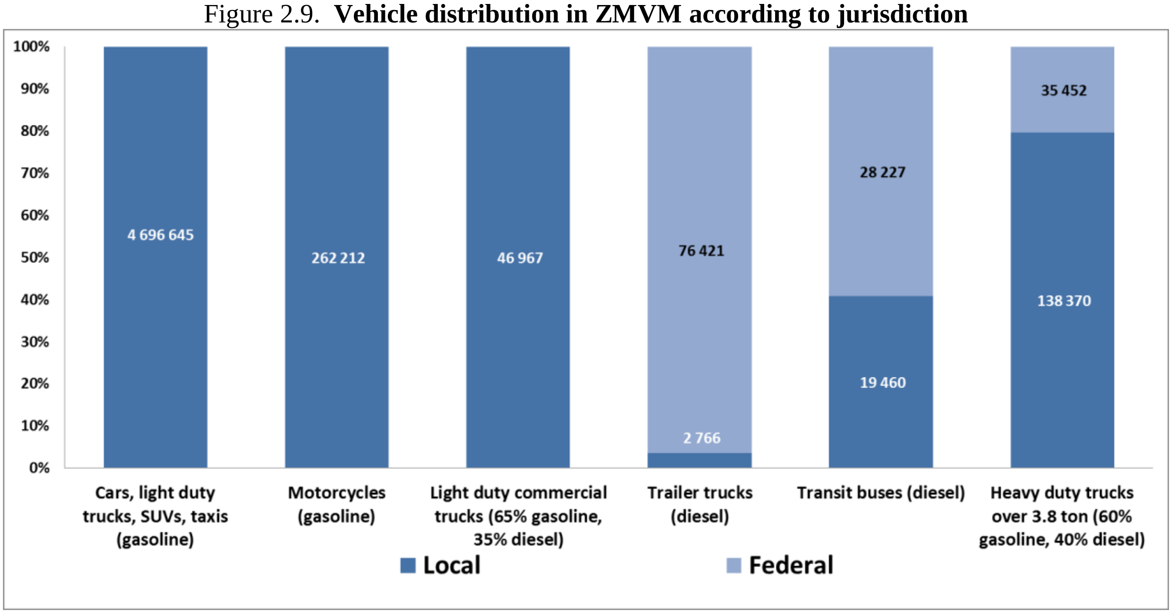
Source: SEDEMA SIMAT.

Measures to control vehicle emissions

A number of complementary instruments have been developed in Mexico to control emissions from the vehicle fleet. The key mitigation mechanisms for the ZMVM are outlined in this section. At a national level, the federal government (through the Ministry for the Environment and Natural Resources, SEMARNAT) is authorised by Mexican environmental law to issue emission control regulations for new vehicles and vehicles in use. The Federal Attorney's Office for Environmental Protection (PROFEPA) supervises compliance with the regulations for new vehicles. The governments of states and municipalities have the responsibility for enforcing regulation of emissions from vehicles in use. The Ministry of Communications and Transport (SCT) ensures compliance with heavy vehicle emission regulations for vehicles registered with a federal number plate. Table 2.3 shows the current regulations for each type of vehicle.

The vehicle fleet in the ZMVM is comprised of vehicles subject to a variety of regulatory regimes and regulatory authorities corresponding to the place where they are registered and the type of vehicle (see Figure 2.9), with the heavy-vehicle fleet particularly heterogeneous.

Figure 2.9. **Vehicle distribution in ZMVM according to jurisdiction**



Source: SEDEMA (2016a).

At a local scale, Mexico City has developed a Mandatory Vehicle Inspection Programme (Programa de Verificación Vehicular Obligatorio, PVVO), a No-driving day programme (Hoy No Circula [HNC]), the Environmental Atmospheric Alert Programme (Programa de Contingencias Ambientales Atmosféricas, PCAA), the Diesel Vehicle Self-Regulation Programme (Programa de Autorregulación de Vehículos a Diésel), an Alternate Fuel Programme (Programa de Combustibles Alternos), the Comprehensive Programme for Reducing Pollutant Emissions (Programa Integral de reducción de emisiones contaminantes, PIREC) and the School Transport Programme (Programa de Transporte Escolar). In addition, through joint action with the federal authorities and the State of Mexico, three Air Quality Improvement Programmes for the ZMVM (PROAIRE initiatives) have been issued, introducing measures to reduce emissions from a range of sectors. The latest programme, PROAIRE 2011-2020, covers eight areas. Strategy 4 addresses mobility, focusing on the systematic planning of transport networks, integration of the transport systems of Mexico City and the State of Mexico and improving the fluidity of traffic flows. Specific measures promote integrated planning with an emphasis on intermodal journeys, traffic monitoring and management, additional express lanes for public transport, promotion of cycling and rationalisation of freight distribution (Government for the State of Mexico et al., 2016).

Table 2.3. **Current vehicle emissions regulations and competent authorities**

	Vehicle type	Regulator	Current regulations	Enforced by
New vehicles	Light duty (cars, SUVs)	SEMARNAT	NOM-042-SEMARNAT-2003 Limits equivalent to those from Tier 1 and 2 USEPA standards, and Euro 3 and 4 (2006 models and on); should have an On-board diagnostics system (OBD II and EOBD)	PROFEPA (document review)
New vehicles	Heavy duty freight and passenger	SEMARNAT	NOM-044-SEMARNAT-2006 Limits equivalent to EPA 2004 and Euro IV (year-models from 2008 and on)	PROFEPA (document review)
Vehicles in circulation	Heavy and light duty in Mexico City, Hidalgo, State of Mexico, Morelos, Puebla, and Tlaxcala states.	SEMARNAT	NOM-EM-SEMARNAT-167-2016 Valid until January 2017. On-board diagnosis system (OBD) check; ASM testing method for vehicles without OBD system, method equivalent to a BAR 90 for heavy gasoline-operating vehicles or those using other fuels; opacity test for diesel-operating vehicles, both heavy and light.	States or municipalities (depending on local legislation) through Vehicle Inspection and Maintenance Programs Federal Ministry of Communications and Transport (for heavy vehicles with federal number plate)
Vehicles in circulation	Light duty (cars, SUVs) for the rest of the country	SEMARNAT	NOM-041-SEMARNAT-2015 ASM testing method, equivalent to BAR 97; for vehicles that cannot be used on a dynamometer, BAR 90 (static method) is authorised. On-board diagnostics system check.	States or municipalities (depending on local legislations) through Vehicle Inspection Programmes
Vehicles in circulation	Heavy duty (freight and passenger transport)	SEMARNAT	NOM-045-SEMARNAT-2006 Opacity measurements	Vehicles registered with federal number plates: Ministry of Communications and Transport Vehicles registered with local plates – state or municipal authorities (depending on local legislations)

Source: Own elaboration with information from Transportpolicy.net

Mandatory vehicle inspection programme and No-Driving Day system

Mandatory vehicle inspection

In the ZMVM the mandatory vehicle inspection programme (PVVO) and No-Driving Day (HNC) programs are linked: the result of the emission inspection procedures determines the way in which a vehicle has to comply with the provisions of the HNC system. The last digit of the vehicle's number plate determines the color-coded category of the HNC system to which the vehicle belongs. This determines the month in which inspections should be carried out (twice per year) and the day of the week on which use of the vehicle is prohibited, when a restriction is applicable.

Until 2015, every inspection program outside Mexico City was based on a static test (equivalent to a US Bureau of Automotive Repair test using 1990 criteria – BAR 90 test). That year, SEMARNAT issued the NOM-041-2015 regulation, requiring all States to use an Acceleration Simulation Mode (ASM) dynamic test (equivalent to a BAR 97 test), which was already in use in Mexico City since the mid-1990s, to measure NOx emissions from all vehicles in use in Mexico. The static test method can now only be used as an exception and States have until 2018 to complete updating of test equipment and procedures.

In the central area of the country, the States of Mexico, Hidalgo, Morelos, Puebla and Tlaxcala have aligned their programs with that of Mexico City in order to avoid restrictions on vehicles entering Mexico City or the municipalities of the State of Mexico that are within the ZMVM for non-compliance with the HNC system. However, few cities in other states have a Mandatory Vehicle Inspection Programme (PVVO). In 2012, only 21 cities had inspection programs and many of these were not mandatory (SEMARNAT, 2012). Their scope and the level of compliance are difficult to determine. Vehicles circulating in Mexico City but registered in these cities or cities that do not have a mandatory inspection programme are likely to have higher emissions on average than those registered in the ZMVM, with a negative impact on the air quality of Mexico City. The use of these vehicles is also therefore restricted once they enter Mexico City or municipalities of the State of Mexico within the ZMVM.

The vehicle inspection programme in Valle de México is the oldest and most mature in the country. It came into effect in 1989 and has been adjusted to adapt to changes in the vehicle fleet and conditions in the city. In 2010, the Mario Molina Center carried out a comprehensive assessment and found that the compliance level for this programme was close to 80%, with most vehicle owners undergoing verification procedures in due time, as required by local regulations (Centro Mario Molina, 2010). Measurements carried out with remote sensing devices[9] in cities across the country show that the emissions from the vehicle fleet circulating in the ZMVM are lower than those in cities with inspection procedures that use static tests or where there is no inspection programme at all (Figure 2.10).

The inspection tests applicable to different generations of light-duty vehicles are summarised in Box 2.4, with the currently applicable tests and emissions limits. Heavy-duty vehicles are also subject to inspection. Vehicles that pass the tests are awarded corresponding certificates and windscreen stickers classified from 00 (cleanest vehicles) to 2. Vehicles that fail inspection can undergo repairs and retesting and may qualify for retrofits of three-way catalysts.

Box 2.4. **Mandatory inspection and maintenance tests (NOM-EM-167-SEMARNAT-2016 standards)**

1. New vehicles:

   a) Mandatory check of On-board diagnostics system on the following five points:
      i. Inappropriate Cylinder Combustion Conditions detection system
      ii. Catalytic Converter Efficiency system
      iii. Fuel System
      iv. Oxygen Sensor System
      v. Comprehensive Component System.

   Every monitoring point has to be functional and must present no failures.

   b) If this condition is complied with, the vehicle is granted a Double-Zero (00) sticker as well as an exemption from inspection for up to two years, renewable for another two years.

2. Vehicles equipped with a three-way catalytic converter and a second-generation On-board diagnostic system (OBDII or EOBD) (model-year 2006 on, according to regulation NOM-042 for new vehicles):

   a) Check of the On-board diagnostic system on the mandatory five points
   Measurement of emission levels through dynamic testing. Emissions should not exceed the following limits:

Maximum allowable limits for gasoline vehicles							
Test	HC (ppm)	CO (%vol)	NO_X (ppm)	$CO+CO_2$ (%vol)		O_2 (%vol)	(lambda)
				Min	Max		
Dynamic	80	0.4	250	13	16.5	0.4	1.03
Static	100	0.5	NA			2	1.03

   b) Vehicles that comply with both conditions can obtain a zero (0) holographic sticker. If not, they can be granted a one (1) holographic sticker or rejection, according to their emissions test results.

3. Vehicles with electronic injection systems (model-year 1994 to about 2005):

   a) Visual smoke detection check-up carried out at 24 km/h
   b) Emission level measurements carried out through dynamic tests should not exceed the following limits:

Maximum allowable limits for gasoline vehicles							
Test	HC (ppm)	CO (%vol)	NO_X (ppm)	$CO+CO_2$ (%vol)		O_2 (%vol)	(lambda)
				Min	Max		
Dynamic	100	0.7	700	13	16.5	2	1.03
Static	100	0.5	NA			2	1.03

   c) Vehicles that comply with both criteria can be granted a one (1) holographic sticker. If not, they can be granted a two (2) holographic sticker or rejected, according to their emissions test results.

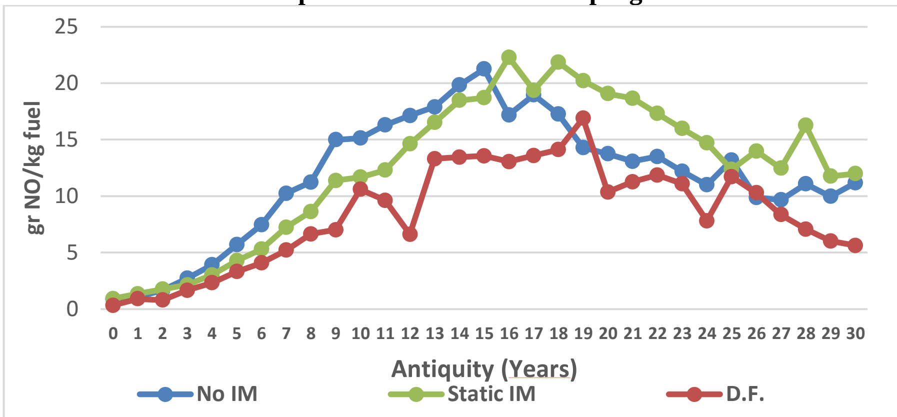
4. Vehicles with mechanical injection systems (model-year 1993 and earlier, approximately)

   a) Emission level measurements through static or dynamic tests should not exceed the following limits:

Maximum allowable limits for gasoline vehicles with mechanical injection system							
Test	HC (ppm)	CO (%vol)	NO_X (ppm)	$CO+CO_2$ (%vol)		O_2 (%vol)	(lambda)
				Min	Max		
Dynamic	350	2.5	2000	13	16.5	2	1.05
Static	4000	3.0	NA			2	1.05

   b) Vehicles that comply with both criteria can be granted a two (2) holographic sticker or rejected, according to their emissions test results.

Figure 2.10. **Comparison of nitrogen monoxide (NO) emissions from vehicles in use in States with and without an inspection and maintenance programme**



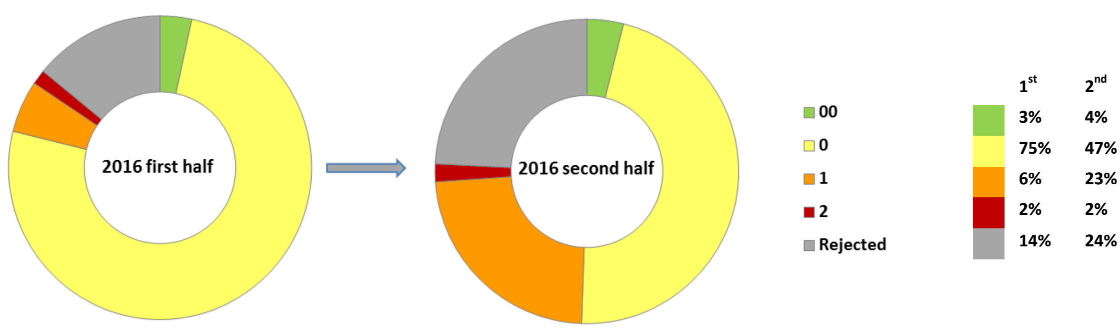
Note: "No IM" = cities with no PVVO; "Static IM" = cities that enforce programs based on static tests; "DF"= Mexico City and its metropolitan area.
Source: Eastern Research Group, Inc., (2016).

The inspection program was modified in 2015 and again in 2016. As already noted, legal challenges to including vehicle age in the conditions for awarding I&M certification were upheld by the Supreme Court in 2015. The system was therefore modified to award certificates purely on the basis of test result, which resulted in an estimated 1.3 million vehicles being reclassified from class 1 to class 0 (thereby escaping restrictions on circulation). The programme was modified again for conformity with the emissions limits established by the emergency regulation, NOM-EM-167-SEMARNAT-2016, issued by the Federal Environment Ministry on 2 June 2016 in response to the episodes of high ozone concentration that occurred between February and May in the ZMVM. This regulation is applicable for Mexico City, as well as the States of Mexico, Hidalgo, Morelos, Puebla and Tlaxcala, coming into effect on 1 July 2016 and renewed for a further six months in January 2017 with a view to nationwide application thereafter.

The 2016 regulation established a number of additional tests depending on the vehicle's emission control technology. The new standard focused on reducing NOx emissions in particular, reducing limits for vehicles from 2006 model year on from 500 to 250 ppm; for vehicles from the 1994 model year onwards from 1 500 to 700 ppm and for older vehicles from 2 500 to 2 000 ppm (see Box 2.4). As can be seen in Figure 2.11, the number of vehicles in the 1 category had collapsed as a result of the 2015 ruling, with more than three quarters of vehicles classified 0 in the first half of 2016. The new regulation has reduced 0 certification to 47% of vehicles tested with 23% in class 1. The CAMe estimates that overall 1.9 million vehicles will lose 0 certification as a result of the change.

Vehicle inspection programs in the CAMe States are currently undergoing modification to make use of OBD inspection across the region, in alignment with procedures in Mexico City. The new tests will be fully operational in mid-2017. At the same time, a failure of vehicle manufacturers and distributors to comply with legal requirements to equip vehicles with second generation OBD systems since the 2006 model year has resulted in major problems for OBD-based inspection. In the second half of 2016 (to 5 December) 111 000 vehicles were rejected by I&M centres in Mexico City because of inoperable OBD or monitoring disabled by the manufacturer (see Table 2.4). The demand for retesting caused congestion in the processing system and delays. Adjustments were made to the process to reduce the need for retesting in October but legal action to enforce the regulation requiring second generation OBD on new vehicles is clearly indicated.

Figure 2.11. **Classification of vehicles under I&M testing in 2016**



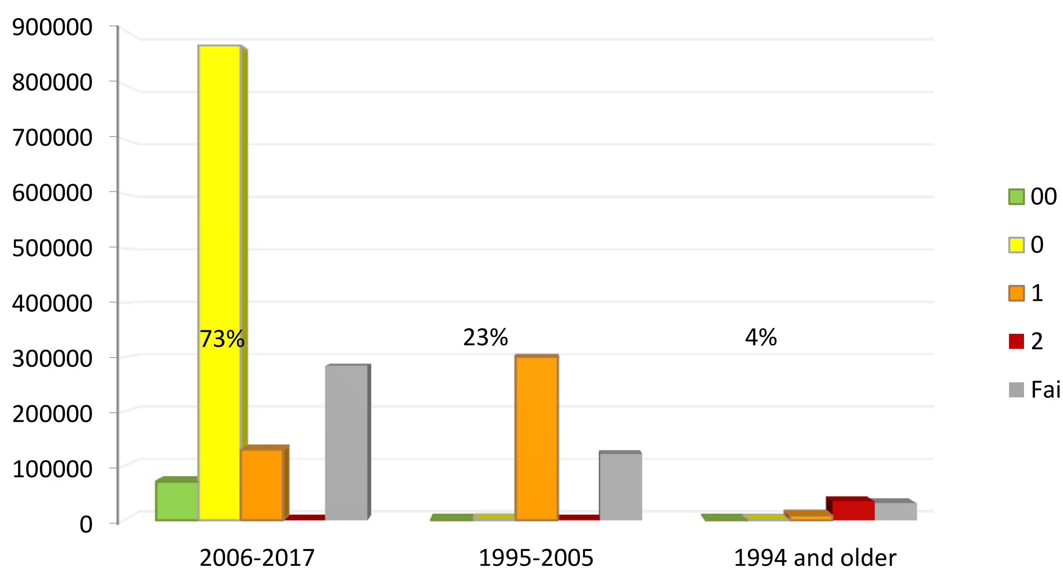
Source: Adapted from SEDEMA data.

Table 2.4. **Causes of rejection under I&M testing in Mexico City 1 July to 5 December 2016**

Cause of rejection	Number of vehicles	Share
Excess emissions	182 756	42%
Inoperable OBD or disabled monitoring	110 937	26%
OBD faults	79 928	18%
Other causes	62 621	14%

Source: SEDEMA.

Figure 2.12. **Classification of vehicles under I&M testing in 2nd half of 2016 by vehicle cohort**



Source: Adapted from SEDEMA data.

No-Driving Day system

The No-Driving Day (HNC) system was introduced in Mexico City in the last quarter of 1989, in response to persistent high concentrations of atmospheric pollutants, prohibiting the use of vehicles one day a week and applicable to all vehicles regardless of emissions control technology or age, and set according to the last digit of the vehicle's number plate. Like the other programmes described, it has undergone modifications according to the results and recommendations of technical studies. Currently, the HNC system restricts vehicle use according to the category awarded (00, 0, 1 or 2) under the periodic mandatory inspection programme. This is indicated by a holographic windscreen sticker. This and the colour of the sticker, which is based on the last digit of the number plate determines on which days of the week use is prohibited. Table 1.7, taken from SEDEMA's website shows the vehicle use restrictions that apply according to holographic windscreen sticker and number plate. Double zero and zero stickers exempt vehicles from restriction.

The holographic windscreen sticker awarded depends on the vehicle's emissions control technology and the results of the tests carried out under the mandatory inspection and maintenance program, as set out in Box 2.5 (SEDEMA, 2016b). A check on catalytic converter operation is also carried out; if its efficiency has undergone a considerable decrease the vehicle is subject to a converter replacement procedure under the Comprehensive Pollutant Emission Reduction Program (*Programa Integral de Reducción de Emisiones Contaminantes*) (PIREC).[10]

Certification and windscreen sticker categories are currently awarded as shown in Table 2.5 for vehicles that comply with the inspection and maintenance tests. The system was last updated in 2016 when, significantly, no-fault OBD test compliance was introduced for all diesel vehicles eligible for 0 certification. This was done to align requirements with the emergency regulation issued by the Ministry of Environment for the ZMVM in April 2016 in response to elevated ozone levels (NOM-167).

Table 2.5. **Summary of vehicle categorisation under emissions testing**

Exempt	**Electric and hybrid vehicles.**
00	New vehicles for individual use under 3.857 tonnes using gasoline or natural gas.
	New vehicles over 3.857 tonnes using diesel that meet Euro VI / EPA 2010 emissions standards and are equipped with particle filters (heavy vehicles using gasoline are not eligible for 00 certification).
0	Vehicles using gasoline, natural gas, LPG and alternative fuels equipped with a three-way catalytic converter and second generation OBD (effectively 2006 models and more recent cars).
	Diesel vehicles from model year 2008 that pass a smoke test (1.0m^{-1} light absorption) and present no OBD faults.
1	Vehicles using gasoline, natural gas, LPG and alternative fuels with electronic injection.
	Diesel vehicles that pass a smoke test (1.2m^{-1} light absorption).
2	Vehicles using gasoline, natural gas, LPG and alternative fuels with mechanical injection.
	Diesel vehicles under 3.857 tonnes that pass a smoke test (2003 models and older 2.0m^{-1}, 2004 models 1.5m^{-1})
	Diesel vehicles over 3.857 tonnes that pass a smoke test (1990 models and older 2.25m^{-1}, 1991 models 1.5m^{-1})

Source: Ciudad de Mexico (2016).

Figure 2.13. **Windscreen sticker (left) and No-Driving Day information display on the Aire mobile phone application (right).**

Compliance with the emission limits as well as with the On-board diagnostic system check is made through authorised Vehicle Inspection Centres. Additionally, measurements are carried out on the streets with remote sensing equipment, on visibly polluting vehicles. Penalties for not complying with the PVVO are significant. Vehicle owners that present their cars late receive a penalty and, in case they are detected by a traffic officer, their vehicle can be detained or confiscated; in addition, the vehicle owner must pay the corresponding fine. Vehicles that do not comply with vehicle inspection requirements can repeat the inspection after repair, but if they fail to comply with the established dates, they are sanctioned.

Vehicles from other states can undergo inspection procedures voluntarily under the Mexico City scheme and be granted their corresponding windscreen stickers, according to their technology and emissions. This is not a requirement, but verification procedures make it possible for them to circulate every day, according to the No-Driving Day provisions.

The HNC system is applicable across all of Mexico City, as well as in the 18 municipalities of the State of Mexico included in the HNC system.[11] The traffic authorities are in charge of supervising the compliance of this program. In case of non-compliance, vehicles are withdrawn from circulation and sent to a vehicle pound. In order to retrieve them, the owner must pay the corresponding fine, and if violation took place on an environmental alert day, they must wait to retrieve their vehicle until the alert is over (Mexico City Government, 2014).

Vehicles with plates that come from states that do not have an agreement with Mexico City and that have not been subject to voluntary inspection in Mexico City cannot be driven in the City Monday through Friday from 5:00 to 11:00 or on Saturdays from 5:00 to 22:00 and, according to the last number on their plates, one day of the week, from 5:00 to 22:00 hours. Circulation restrictions are stricter when the Atmospheric Environmental Alert Program is activated.

Although it has been observed that the HNC system has encouraged households to purchase additional vehicles to escape restrictions and thus increased the number of vehicles circulating in the city, the vehicle fleet in Mexico City is cleaner and more modern than that in the rest of the country (as shown in Figure 2.10). This program, along with the PVVO, has probably resulted in an accelerated renewal of the vehicle fleet (due to the advantages accorded the most recent vehicles). This is consistent with a study of the vehicle restriction program for Santiago de Chile, where they found that due to exemptions being granted to vehicles with advanced emission controls, the program had encouraged vehicle fleet renewal (Barahona et al., 2016).

Atmospheric Environment Alert Program (PCAA)

This program includes a series of measures to cope with episodes of high concentrations of ozone or particulate matter (PM_{10}) recorded by the Environmental Monitoring System (SIMAT). These measures are applicable within the 16 territorial delegations of Mexico City as well as 18 municipalities of the State of Mexico included in the HNC system. Until April 2016, this program included three stages: pre-alert, Stage I Alert and Stage II Alert. The pre-alert stage was activated when pollutant concentrations reached 150 IMECA points. The programme was established in 1988; since then, its activation thresholds and response measures have undergone modification. From June 2008 on, limits for both pre-alert and alert phases were lowered, and in April 2016 the pre-alert stage was eliminated altogether and in December 2016, air quality forecast was introduced as part of the programme (SEDEMA, 2016c).

The alert program includes measures to reduce exposure to pollution (for instance restriction of outdoor activities), restrictions on the use of some vehicles and measures to reduce emissions from other sources. These include controlling PM_{10} and ozone precursor emissions in the service sector (road surfacing and repair, wood combustion, and a 20% reduction in the distribution of liquefied petroleum gas for vehicle refuelling) and in the industry sector (aiming at a reduction of 30-40% of particulate and ozone precursor emissions by restricting the activity of un-controlled fixed emissions sources).

Table 2.6. **Mobility restrictions during environmental alerts**

Alert level	Activation points (Air Quality Index) Ozone PM_{10}	Mobility restrictions	Alert suspension points
Stage I	Over 150	- Vehicles with class 1 holographic windscreen stickers restricted on alternate days according to the last digit of their number plate, odd or even. Vehicles with class 2 holographic windscreen stickers are restricted on all days during the alert. (Class 0 and 00 vehicles are exempt from restrictions but were restricted on alternate days during the alerts between April and July 2016). - Freight transportation (federal or local plates) prohibited between 06:00 and 10:00. Trucks carrying perishable products restricted to operate between 22:00 and 05:00 in Mexico City	Equal or less than 150 and air quality forecast
Stage II	Over 200	- Every vehicle with a 1 or 2 holographic windscreen sticker prohibited. (Type 0 and 00 exempt). -Freight vehicles restricted on alternated days according to the last number on their plate (local plates) and third number (federal plates).	

Source: SEDEMA (2016c).

The SIMAT records concentrations and alerts for the CAMe, which in turn issues alerts. From the moment an alert it is declared, environmental pollutant concentrations are continuously evaluated with reports issued to the public at 10:00, 15:00 and 20:00.

Currently, Environmental Alerts are declared within the hour following the recording of ozone and particulate concentrations at any SIMAT monitoring station that generates the Air Quality Index activation point levels indicated in Table 2.6. Emergency service vehicles, transport for disabled people, school buses, refrigerated trucks, concrete mixers, funeral vehicles and motorcycles are not subject to these restrictions. In the case of particulate matter alerts, a regional alert is declared if high concentration values are only recorded by the monitoring station in the area, and an alert for the entire metropolitan area declared if there are two or more zones recording high levels, this determines the territorial extent for application of restrictions.

Other emissions control measures

Several additional pollution mitigation measures in the transport sector have been introduced as follows (SEDEMA, 2016d):

- Voluntary diesel vehicles programme (Programa de autoregulación): This program is designed for freight and public transport. Under the programme, owners of these vehicles agree to undertake preventive maintenance and measure vehicle emissions (on a bi-annual basis for freight and on a quarterly basis for public transport) in exchange for an exemption from the HNC program. The self-regulation program also comprises a vehicle renewal program in order to replace existing units with cleaner, more efficient vehicles, such as EURO VI and EPA 2010 compliant trucks, or retrofit emission control systems (oxidation catalysts and particle filters). In November 2016 there were 9 235 vehicles registered under this program, belonging to 30 own-account operators and 13 passenger transport companies.

- Retrofit program for buses: Since April 2015, pilot tests have been carried out for the installation of particle filters on vehicles. Filter installation is programmed for 540 public buses and school busses, aiming to achieve an estimated reduction of 8 tonnes/year of PM10 and 7 tonnes/year of PM2.5. In May 2016, the Official Gazette published the call for tender for "Authorization as a distributor of oxidation catalysts and diesel particulate filters for vehicles circulating in Mexico City". Four authorisations had been issued for particle filters as of May 2017 and one for oxidation catalysts; the call is still open.

- Comprehensive Pollutant Emission Reduction Program (Programa Integral de Reducción de Emisiones Contaminantes - PIREC): Under this program a pilot in the second half of 2014 provided for free replacement of catalytic converters for light-duty vehicles that are over 15 years old, and replacement of catalytic converters on more recent vehicles where failures were detected during vehicle inspection tests. In 2014, at no charge, 30 221 converters were installed on light-duty vehicles that were older than 15 years and in the last two years 14 703 catalytic converters were fitted on vehicles rejected in emissions testing through seven companies at 126 workshops. In March 2016 a call for authorised distributors of catalytic converters for vehicles with second generation on-board diagnostic systems (OBDII) was published in the Official Gazette, in order that replacement converters are available for vehicles that present faults in their emissions control devices. Catalytic converters reduce NOx, CO and HC emissions more than 70%.

- School transportation program: This program establishes that elementary and junior high schools with over 490 students should implement a mandatory collective school transport program for all their students, making an exception for those who arrive walking or on bicycle, those who have any disabilities, those who are not covered by established bus transport routes or whose families work on campus. This program initiated in2009 in schools with over 1 240 students and, since 2011, is being implemented in schools with over 670 students, progressively incorporating more schools. Currently, 63 schools participate in this program.

Results of the measures

Currently, Mexico City has about 66 inspection centres with 340 vehicle verification lines. Each semester about 1.8 to 2 million units are tested. Reports issued by SEDEMA indicate that models 2006 and on are mostly granted a type 0 windscreen sticker, while 1994-2005 models are granted type 1 windscreen stickers and 1993 or older get a type Two sticker (SEDEMA, 2016c).

The Ministry of Environment of Mexico City grants authorisations to operate inspection centres and determines maximum prices for inspection. The last tender for inspection centres was published on 3 July 1996, from which 71 Vehicle Inspection Centres are still in existence and operating. These have since renewed their authorisations, but these will all expire on 31 December 2017.

For the last semester (1 July to 5 December 2016), the rejection rate was 23%, with over 436 000 vehicles. For the most part (65%, 284 300) of these were model-year 2006 and on, despite having three-way catalytic converters and On-board diagnostic systems as required by the Mexican regulation. The most frequent rejection cause was non-compliance with the limits, followed by rejections due to the fact that the On-board diagnostic system was not enabled by the manufacturer, or a failure on the unit connector that impairs communication with the on-board computer system (SEDEMA, 2016c). This is, to a great extent, attributable to inadequate maintenance.

Even though the most recent vehicles (year 2016 and 2017 models) should be able to obtain a Double-Zero type windscreen sticker, statistics from the second semester of 2016 show that over 20% of these vehicles did not obtain their two-year verification exemptions; 8% were rejected, 13% were granted a type Zero windscreen sticker (due to emissions exceeding the limits for 00 stickers) and 2% were granted a type One holographic sticker for the same reason. The top ten manufacturers with a high percentage of new vehicles that were unable to obtain type Double-Zero stickers were: Renault (Kangoo 94%, Fluence 94%), Fiat (Palio, 79%), Chrysler (Vision, 79%), Toyota (Yaris, 73%), Ford (Lobo, 67%), Ram (700 Club Cab, 66%), Toyota (Corolla, 64%), Ram 700 (60%). The main cause of rejection in most cases was connection errors or "non-completed" monitoring. However, SEDEMA has detected brands that have recurring issues with their Cylinder Connection Inadequate Situation Detection systems (SDCIIC), or with their fuel system monitor (SC), or with their integrated component system (SEDEMA, 2016c).

Table 2.7. **Emissions testing pass and fail rates, Mexico City 2016**

Number plate	**5 + 6**	**7 + 8**	**3 + 4**	**1 + 2**	**9 + 0**	**TOTAL**
Approved	317 314	302 535	290 049	294 424	296 680	1 501 002
Missing	49 171	56 694	58 830	56 659	57 353	278 707
Missing %						16%

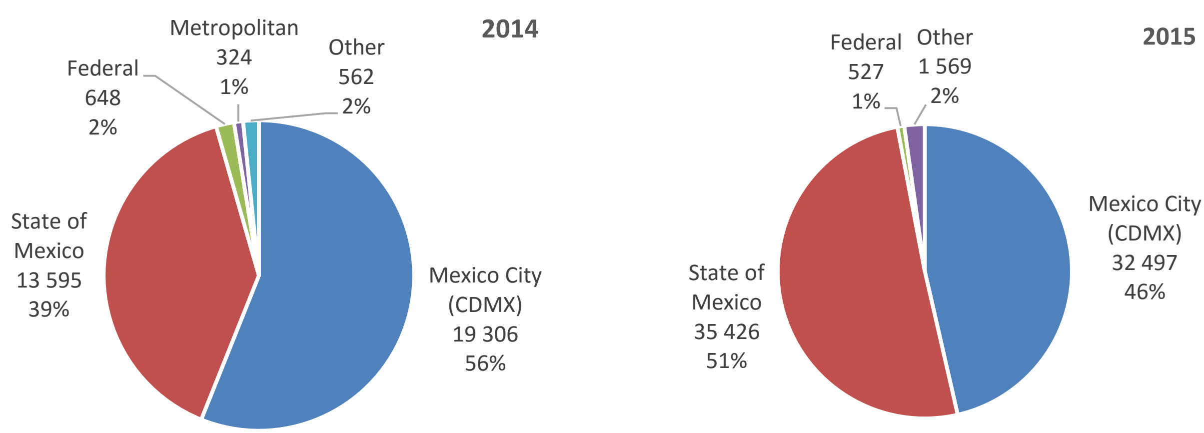
Source: SEDEMA.

It is important to mention that the measures to regulate emissions have become stricter in Mexico City. This has reduced the vehicle fleet registered in the city, since automobile owners have changed the registration and plates of their vehicles to those from other States where regulations are lax. Work for homogenising regulations is currently taking place.

Table 2.8 shows the number of vehicles that were approved through the vehicle inspection programme during the second semester of 2016, categorised according to the last digit of their plate, and which in turn defines the colour assigned. The table also shows vehicles that were not processed in the vehicle inspection programme during the second semester but did go through testing during the first semester of the year.

The vehicle fleet inspected during the second semester included about 300 thousand vehicles from each colour code. This includes vehicles with holograms "00", "0", "1" and "2. About 50 000 vehicles from each group did not go back to the programme in the second semester. A similar deficit was observed in roadside testing with a remote sensing device in the ZMVM. Figure 2.15 shows the place of registration of the vehicles tested; Figure 2.14 summarises the results of emissions testing.

Figure 2.14. **Vehicles tested on the road with a remote testing device in the ZMVM in 2015 and 2014**

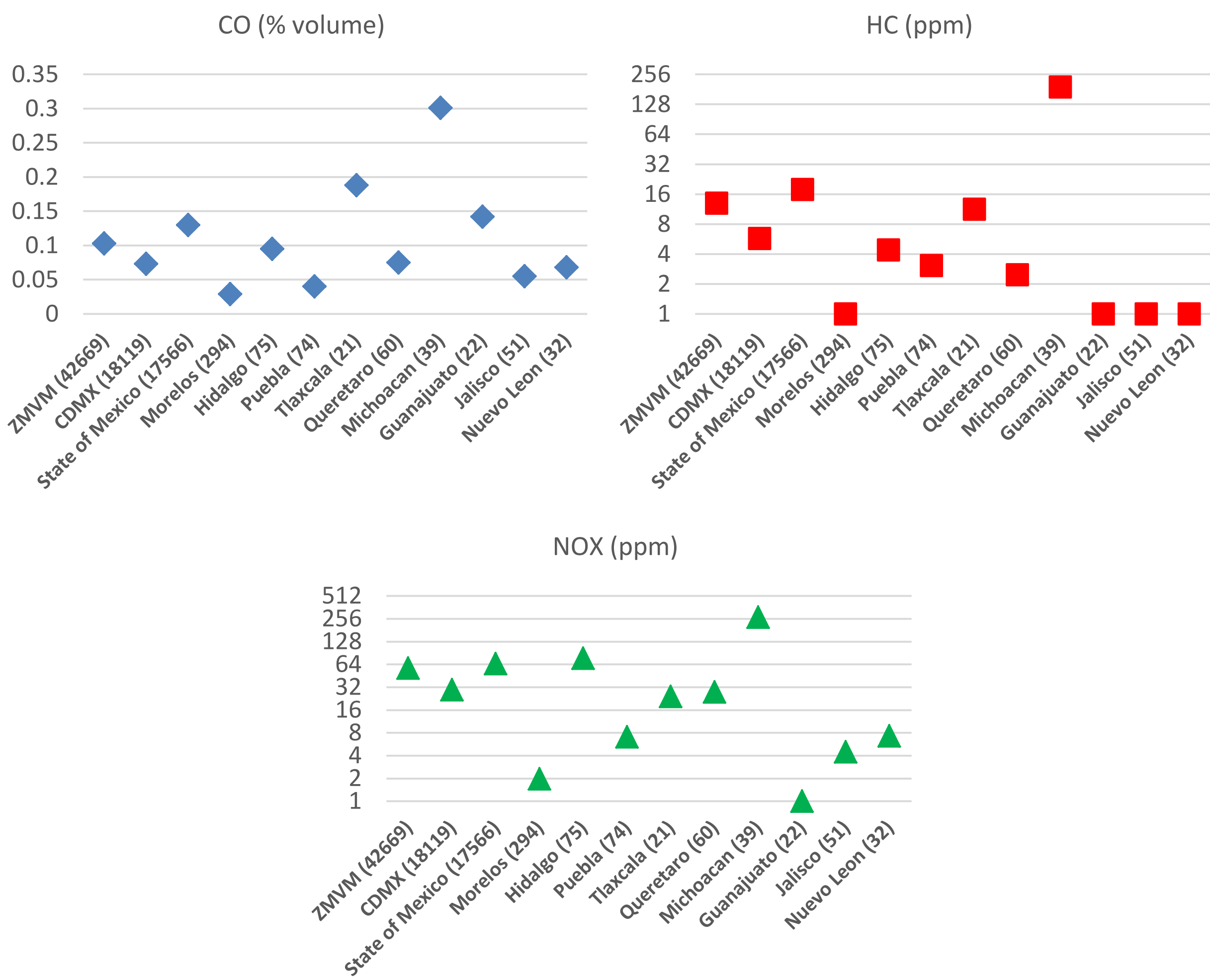


Source: SEDEMA.

From Figure 2.15, the following can be observed:

- Vehicles registered in the State of Mexico show higher emission concentration levels than those registered in Mexico City for the three criteria pollutants. The sample for each state is of about 18 000 vehicles.
- Vehicles with the highest CO concentrations were those registered in Michoacán, Tlaxcala and Guanajuato; those with the lowest concentrations were those registered in Morelos, Puebla and Jalisco.
- The highest HC concentration level was shown by vehicles registered in Michoacán while the lowest concentrations were shown by vehicles in Morelos, Jalisco and Nuevo León.
- In the case of NO_x emissions, the highest concentration was also shown by vehicles registered in Michoacán, while the lowest by vehicles from Morelos and Guanajuato.

Figure 2.15. **Exhaust gas emissions concentrations for vehicles tested in the field in the ZMVM by place of registration (Median values for the month of testing)**



Source: SEDEMA.

Low emission zones

Recently, some cities within the Megalopolis[12] have started designing and developing pilot programs in order to implement low emission zones (LEZ). LEZs are fairly common in European cities. Although there is not an exact definition, since their design has some variation by city, these zones are generally geographic areas within which a certain type of motor vehicle has restricted access. Commonly, these are the most polluting vehicles. It should be noted that the effectiveness of an LEZ depends mostly on the appropriate definition of at least the following three characteristics:

1. Type of vehicle use restriction: Generally LEZs impose a complete prohibition for those vehicles that fail to comply with required specifications. However, some schemes allow access in exchange for a significant payment.[13] In addition, it is necessary to define days, schedules, air quality limits and extraordinary situations, such as peak pollution episodes, that would be applicable to the LEZ.

2. Regulated vehicles: Since the regulation can be applicable to combinations of passenger and freight vehicles, diesel and/or gasoline vehicles, etc., it is of the utmost importance to analyse whether the application to any particular sector would have a greater impact, if its implementation would be made easier, or if there are any elements on the current regulation framework that could have an effect (positive or negative) on the effectiveness of the LEZ.
3. Geographic area: The main European cities where these zones have been established have defined fairly extended areas. Since their goal is to reduce population exposure to pollutants, the size of the LEZ should be one that guarantees minimum pollutant dispersion within it but also encourages an accelerated vehicle fleet renewal, thus extending the effects of this program to zones outside it.

Cities such as Cuernavaca and Toluca have extended the concept of the LEZ and are working on the implementation of eco-zones. Inspired by the LEZ, these zones aspire not only to reduce pollutant emissions, but also to improve urban spaces, promote non-motorised mobility, reduce road accident rates and encourage economic activities within the area. Table 2.8 presents the definition, objectives and the relation with air quality of the proposals in Cuernavaca and Toluca.

Table 2.8. **General description for Cuernavaca and Toluca eco-zones**

	Cuernavaca	Toluca
Coverage area	1.8 km^2, centre of the city	2.6 km^2, centre of the city
Specific definition and eco-zone objective, as defined by the city	The eco-zone is an area of intense urban activity. The goal is to implement actions in order to reduce polluting emissions and recover environmental value areas.	The eco-zone is an environmental priority area; its goal is to improve living quality for its inhabitants and residents through the implementation of comprehensive actions that reduce pollution, improve public spaces and promote sustainable mobility.
Implementation details	There are currently no specific programs; the city is still analysing applicable alternatives.	Eco-zone programs are divided into seven categories: public lighting energetic efficiency, solid waste management, public spaces, urban development, environmental education, pollution and smart mobility.
Air quality specific details	According to their preliminary plan, one of the main goals within the eco-zone is to reduce those pollutants the population is exposed to, thus mitigating negative health effects.	The current plan does not contemplate any action related to internal combustion vehicles, except for parking control on the smart mobility program.

Undoubtedly, eco-zones could be an important tool for urban economic and environmental management. However, the pursuit of numerous objectives through a single tool demands additional efforts in order to guarantee that the necessary elements for achieving each objective are effectively included in the regulatory design.

Without undermining the other goals pursued by the eco-zones, Mexico City would benefit most if they first design an LEZ to improve air quality. This would not prevent additional mechanisms being included gradually in the LEZ over time. One advantage of concentrating on air quality resides in the international experience available in the design of an effective instrument. Table 2.9 shows basic design elements for some of the European LEZ.[14]

Table 2.9. **Low emission zone basic characteristics in European cities**

	Stockholm	London	Milan	Berlin
Implementation year	1996	2008	2011	2008
Regulated vehicles	Trucks and buses with a weight over 3.5 tonnes and over eight years old	Trucks with a gross weight over 3.5 tonnes. Buses with a gross weight over 5 tonnes. Vans and pick-ups based on their gross weight and antiquity	Trucks, buses and passenger cars	Trucks, buses and passenger cars
Fuel	Diesel only	Diesel only	Diesel and gasoline	Diesel and gasoline
Low emission zone dimensions	30 km^2	~1 000 km^2	~1 100 km^2	88 km^2
Operative hours	Permanently, all year round	Permanently, all year round	Differentiated daily schedule. Variations according to the month of the year	Permanently, all year round
Optional fees*	Not allowed	Allowed Between USD 140 and 240 a day	Not allowed	Not allowed
Fines*	USD 120	USD 360-1 440 (50% reduction if it is paid within the first 14 days)	Between USD 85 and 513	USD 90
Verification	Monitoring carried out by the police, based on the vehicle's certificates	Electronic system with plate recognition cameras	Monitoring carried out by the police, based on the vehicle's certificates	Monitoring carried out by the police, based on the color of their windscreen sticker

*Fees and fine amounts correspond to information from April 2016. Local conversion to USD is based on the average exchange rate for the same month.
Sources: General characteristics of European regulations, available at: http://urbanaccessregulations.eu/

The cases of Stockholm, London, Milan and Berlin and other cities show that despite their differences, two common elements can be identified and should be taken into consideration if case Mexico City aspires to implement a LEZ:

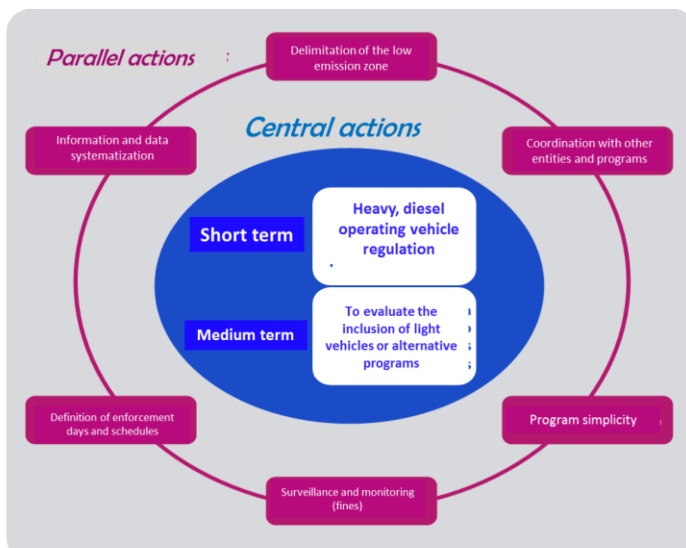
1. The surface of the LEZ must be proportionate, regardless of its absolute size, and sufficient in extent compared to the total area of the city if it is to be effective. Size varies from about 30 km^2 for Stockholm to 1 000 km^2 for London.
2. Restriction of access for heavy diesel vehicles - trucks and buses - is common to every LEZ. Some eco-zones regulate light-duty gasoline vehicles as well, but the greatest focus is on heavy-diesel vehicles.

Accordingly, an LEZ that focuses on heavy-diesel vehicles in Mexico City could be an effective tool for local pollutant reduction. Those diesel vehicles are responsible for over 90% of particulate matter ($PM_{2.5}$) emissions from traffic in Mexico City and for about 50% of nitrogen oxide (NO_X) emissions (SEDEMA, 2016a).

It is suggested that the implementation strategy considers a range of actions for both the short and long term. Figure 2.16 shows these elements graphically. As a central short term action, the establishment of a regulatory provision for an LEZ for heavy vehicles operating on diesel is the main goal. Taking that as a starting point, parallel actions are developed, including the definition of the area to be covered, schedules, monitoring and surveillance systems.

It is important to observe that in the medium term, the inclusion of light-duty vehicles and of additional programmes within the LEZ can be considered. However, in order to avoid hindering the regulation process and thus deferring benefits from emission reduction including the immediate health impact, it is suggested that actions that have proved to produce results in other cities have the highest priority. Finally, it is important to carry out an assessment of the relevance and feasibility of linking Mexico City's LEZ with other programmes that have already been established and could enable the implementation of the LEZ and create synergies.

Figure 2.16. **Low emission zone implementation framework**



Programmes focused on the freight sector that will be the main subject for this analysis include the following initiatives (German Cooperative for Development et al., 2015):

1. **Clean Transportation Program**: This is a voluntary program from SEMARNAT that has the purpose of making freight and passenger transport more efficient, through the adoption of strategies, technologies and better practices. Transport companies as well as users of freight transport record actions taken in order to reduce their emissions as well as their fuel consumption, in exchange for consultations, training and, occasionally, financing for the incorporation of new technologies.

2. **Vehicle Substitution Scheme**: This programme operates under the Decree for the Substitution and Vehicle Renewal Scheme (*Decreto para el Esquema de Sustitución y Renovación Vehicular*) issued on the Official Gazette on 30 October 2003 (Decree), by which a fiscal incentive is granted to the contributor (heavy vehicle assembly plants and distributors) taking as a reference the compared value of the destroyed unit against the value of a semi-new or new unit to be purchased.

3. **Federal Auto-Transportation Fleet Modernisation Program**: Operated by *Nacional Financiera* (NAFIN), its goal is to enable the renewal of the freight and passenger federal transport fleet on a national level. Through this mechanism, transport companies can access financing in order to purchase semi-new and new trucks of less than six years. In order to increase credit granting and thus enabling more unit renewal, the Federal Government offers counter-guarantees to the interested financial intermediaries.

Outline of other policies considered for development of a new strategy to reduce air pollution

Following the episodes of high pollutant concentrations in the first semester of 2016, several institutions developed documents with recommendations for additional measures to reduce ozone concentrations in the ZMVM and avoid these episodes. The Autonomous National University of Mexico (UNAM) presented a series of suggestions through a press release, synthesised as follows (Dirección General de Comunicación Social de la UNAM, 2016):

- Implement a selective control for those sources that emit volatile organic compounds (VOCs) that promote ozone formation, instead of indiscriminately reducing vehicle emissions.
- Include those industries or services that make profuse use of organic solvents, such as furniture manufacture, metal-working and car painting repair.
- Broaden the application of the emissions controls programmes to the 42 municipalities from the State of Mexico that are not currently included but are part of the same atmospheric zone that Mexico City belongs to. Accordingly, impose a control system for fugitive VOC emissions from petrol fumes at gas stations in these municipalities.
- Promote safe, high quality public transport in order to avoid additional vehicle acquisition.
- Demand that vehicle manufacturers comply with stricter emission standards. Mexican Federal Government should guarantee better quality for fuel supplies as well as verify vehicle and fuel regulation is complied with.
- Strengthen and maintain monitoring networks and strengthen the capacity of federal agencies that are part of the CAMe.
- Fight corruption in verification centres.

In May 2016, the Mario Molina Center presented six priority strategic lines for reducing emissions (Centro Mario Molina, 2016):

1. Accelerate the development of low emission public transport systems of high quality and integrated at a metropolitan scale. Extend BRT mass transportation systems by at least 40 km each year and integrate the systems of Mexico City and the State of Mexico in order to harmonise service quality and prices, focusing on surrounding municipalities in the State of Mexico. Immediately initiate pending projects such as the subway network expansion, eight Metrobus lines and five Mexibus lines.
2. Promote more rational use of cars as well as clean technologies. Fix prices for fuel that reflect their externalities, at rates that discourage car use, introduce congestion charges and introduce parking space limitations and a tax or rent associated to the value of parking spaces and related to the vehicle’s dimensions and emissions. Encourage a technological transformation for transportation (with incentives for electric and hybrid vehicle acquisition, programmes for the installation of particle traps on buses, accelerate catalytic converter replacements).

3. Drastically reduce freight emissions. Update the NOM-044 regulation for new vehicles as well as extending the parameters and procedures of NOM-045 for vehicles in use; guarantee a strategic supply of ultra-low sulphur diesel on priority corridors; establish schedules and routes for access and circulation of freight within the ZMVM; generate incentives in order to strengthen vehicle scrapping programmes for obsolete, heavy vehicles and limit the entrance of vehicles from outside ZMVM.
4. Update regulations on vehicle inspection to guarantee compliance.
5. Reduce pollutant emissions that come from industrial activities as well as fuel distribution; and prevent and avoid fires. Update emission regulations for specific sources; assess the closure or relocation of industrial sources that affect high population density areas; generate environmental auditing emergency programmes that focus on reducing VOCs, NO_x and particulate matter; control liquefied petrol gas as well as natural gas leakages, control vapour fumes generated by diesel and gasoline in service stations; control forest fires.
6. Contain the expansion of the urban area in order to reduce mobility demand. Develop a Territorial Regulation Program on the megalopolis scale and update the Urban Development General Program for the city, focusing on mixed land use and consolidation around poly-centres, in order to de-concentrate activities and travel.

The CAMe and its technical consultants are currently analysing these and other measures in order to reduce the occurrence of critical atmospheric pollution episodes and improve Mexico City's air quality in the long and short term.

3. Real-world vehicle emissions

The current state of affairs in Europe[15]

Real-world vehicle emissions differ from the legislative emissions limits for a number of reasons. In most cases emissions, in grams per kilometre, are higher than the type-approval, or factory value. But emissions can also be substantially lower. This section aims to outline the main reasons for the deviations and the implications for managing air pollution. The European situation is taken as example.

In the past attention was directed mainly at the reduction of the emissions of heavy-duty vehicles. However, the latest generation of Euro-VI diesel trucks are very clean. They typically perform better on-road than the type-approval limits. Basically, the average modern 30-tonne truck has a lower Nitrogen Oxide (NO_x) emission than an average modern diesel passenger car. Combined with the increased share of diesel passenger cars in the total fleet attention has shifted to these diesel passenger cars and to light commercial vans. The separation between light-duty and heavy-duty emission legislation lies at 3.5 tonnes in Europe.

Only recently, with the influx of these Euro-VI diesel trucks from 2014 onwards, has the impact of heavy-duty vehicles on the total NO_x emissions declined. Trucks were responsible for more than half the NO_x emissions in many traffic situations on urban roads, despite the small fraction of trucks among the vehicles, 5% or less. The selective catalytic reduction (SCR) emission after-treatment system, used since 2007 on trucks, functioned only in circumstances similar to the European Transient Cycle (ETC) type-approval test. The corresponding on-road circumstances are heavy-loaded driving on the motorway. In urban conditions the SCR system remained too cold to function and the NO_x emissions of Euro-V trucks are typically threefold to fivefold higher than the regulated limit.

With Euro-VI legislation for heavy-duty engines, there are three important changes. First, the new engine test, the World Heavy-duty Transient Cycle (WHTC), uses a lower engine load more comparable to on-road usage. Second, a cold start is included in the test protocol. Finally, and maybe most important for the success of Euro-VI legislation, the in-service conformity (ISC) test is no longer an engine test in the laboratory but an on-road test with the vehicle in normal use. The NO_x emissions of the first Euro-VI trucks were extremely low; in a number of cases close to the bounds of measurement uncertainty. Moreover, with continued testing emissions remain, in general, low for Euro-VI trucks with aging of the first vehicles and with new engines coming onto the market.

There are minor concerns for high emissions in special urban use, such as refuse trucks and inner-city busses, which still operate mainly outside the in-service conformity test regime.

Robust emission control technologies

In the last thirty years there have been two emission control technologies that have changed the landscape for vehicle emissions. These are the three-way catalyst for petrol cars, and the diesel particulate filter for diesel vehicles. Around 1990 the three-way catalyst was introduced for spark-ignition vehicles, such as petrol cars. This decimated the emissions of hydrocarbons (HC), carbon monoxide (CO) and nitrogen oxides (NO_x) of these vehicles (emissions of particulates [PM] were already low for petrol vehicles), and it left diesel vehicles as the main polluters from 1992 onwards. Apart from cold starts, aging and some failures in engine control systems, especially prior to 2000, the emissions of petrol cars have been very low. A catalyst requires time and fuel to warm up. The cold-engine start yields higher initial emissions before the catalyst is warm. For petrol cars these so-called cold-start emissions dominate total emissions, in particular for HC emissions.

The diesel particulates filter (DPF) has been standard for diesel passenger cars since 2009 and for trucks since 2014. The addition to the European regulations of a particulate number emission limit, accompanied with a measurement procedure which can detect particulates accurately in the lower end of the size range, ensured appropriate application of DPF technology. The change in particulate emissions with the introduction of the filter has been dramatic. The particulate mass limit was reduced by a factor of five for diesel passenger cars between Euro-4 (2005) and Euro-5 (2009) standards but the real-world emissions decreased by at least a factor of fifty. Prior to the widespread application of DPFs, the average real-world particulate emissions of diesel cars were somewhat higher than the limits. For vehicles with a DPF the emissions are far below this limit. The actual values are often around 0.5 mg/km, close to the measurement uncertainty, while the limit is 5 mg/km.

The type approval test as the standard for compliance

The type-approval test for light-duty vehicles is executed on the prototype of a new vehicle model, and repeated occasionally in the conformity-of-production tests on new vehicles directly from the factory. The type-approval test is a well-defined protocol, with limited power demand on the vehicle, such that all vehicle models can undergo the same test. Hence the demand on the engine during the type-approval test is only a fraction of the typically available engine power in a modern European light-duty vehicle. If vehicles in use are taken from the road to undergo these tests, the emissions are usually slightly higher but the performance on the type-approval test is generally satisfactory. Occasionally, high emissions from in-use vehicles on the type-approval test occur due to malfunctioning or poor maintenance of the vehicle.

Contrary to light-duty vehicles, the engine demand in the type-approval test of a heavy-duty vehicle is on the high side of the engine demand profile for normal use of trucks. For heavy-duty vehicles the type-approval emission test applies to the engine rather than the whole vehicle, and is based on the rated power of the engine. With the general increase in engine power over the years, the engines have been tested with higher and higher engine loads, while the real-world engine load remained more constant, and unrelated to rated engine power.

Thus the type-approval test for light-duty vehicles is focuses on the weakest link, low-powered vehicles, while the heavy-duty engines are tested on high engine loads matched to engine power. Both type-approval tests therefore cover only a particular part of the engine load spectrum observed in real-world usage.

The two separate worlds of type-approval and on-road in-use testing for light-duty diesel vehicles

In the real world, emissions can be much higher than on the type-approval test. This is particularly the case for light-duty diesel vehicles. Recently, the “dieselgate” scandal with modern vehicles switching to a customised emissions control strategy during type-approval and conformity of production tests caught everyone’s attention, but there has been a steady increase in the difference between the real-world emissions of light-duty diesels and the type-approval limits for at least a decade. This increase coincides with the increasing complexity of emission control strategies and the electronic sensor and control systems of the vehicle. Engine control nowadays is related to gear selection, ambient temperature, fuel quality and so on. Within the full span of driving behaviour, vehicle payload and ambient conditions the specific conditions of the type-approval test are a smaller and smaller subset, with an increasing number of parametric dependencies. Optimising emissions control technology on this subset of operating conditions leads to a larger and larger area where emission control is of limited effectiveness. Around the year 2000, high emissions were typically only observed under hard acceleration. Nowadays, temperatures below 20°C, high engine speeds, high engine loads, speeds above 120 km/h, use of running lights can all result in cases where disproportional increases in vehicle emissions are observed.

In particular over recent decades, real-world NO_x emissions from diesel vehicles have remained high, at about 0.6 g/km, despite the emission limit changing from 0.97 g/km (combined NO_x and hydrocarbons [HC]) for Euro 1 legislation in 1992 to 0.080 g/km (NO_x alone) for Euro 6 standards in 2014. Seemingly, the applied emission control technology, which performs excellently in the type-approval tests, has limited effectiveness in any other circumstance than the type-approval test. NO_x emissions from light-duty diesels are high in almost all normal conditions on the road and for all vehicle models until 2016.

Very recently some well-performing vehicles have entered the market, with on-road emissions approaching the type-approval limit of Euro-6.

Designed, or optimised, for the type-approval test

Given the precise protocol and the limited demands on engine power in the type-approval test, some technologies can be designed for the type-approval testing that are less suitable for other vehicle use conditions, in particular for higher engine power and dynamic driving. For example, an after-treatment system can be designed for a maximum exhaust gas flow or a maximal amount of pollutants that can be reduced. If this maximum is related solely to values occurring on the type-approval test, the emissions will increase substantially in the real world with higher flows resulting from harder accelerations and higher payloads.

Also engine temperature management is a complex matter, where the optimal operation of an engine, including durability considerations, can be at odds with the emission control system. Most diesel vehicles use exhaust gas recirculation (EGR) to limit the NO_x emissions during combustion. The combination of more inlet exhaust gas and less oxygen (fresh air) in the cylinder reduces the combustion temperature and hence the production of NO_x. The amount of recirculated exhaust gas depends on the power demand, the inlet pressure and temperature and other factors which depend strongly on the precise operating conditions. Therefore, the EGR rate is dynamically controlled, and in the case of high power demand, it can be restricted. NO_x emissions can increase easily by a factor of three or more when the EGR rate is reduced. Such circumstances may not occur in the type-approval tests but can be common in on-road situations. The particulars of EGR control strategies have been key to the high real-world NO_x emissions of Euro-5 diesel cars, sold in Europe between 2009 and 2015. The real-world emissions of these vehicles are on average four times higher than the type-approval limit.

Around 2010 a number of vehicles showed high NO_x emission levels in independently executed type-approval test carried out at a laboratory temperature of 15°C instead of the 20°C to 30°C window prescribed in the type-approval procedure. The rest of the test protocol was identical but the emissions were about three times higher than at 20°C. It was considered an improper emission control strategy to have such a large increase for such limited variation outside the test protocol. On the other hand, there was no implementing regulation which set a precise limit on the acceptable increase in emission while deviating outside the operation region of the type-approval protocol.

With Euro 6 compliant control technologies the situation is even more complex, in addition to EGR most vehicles are equipped with additional after-treatment technology for NO_x reduction. This is typically a lean NO_x trap (LNT) or a selective catalyst reduction (SCR) system. The latter uses a urea solution (AdBlue) to reduce NO_x to harmless components. For most Euro 6 vehicle models real-world NO_x emissions are still very high, but occasionally models are found with low emissions. The reasons why a large number of diesel Euro 6 vehicles perform poorly on NO_x emissions tests in many real-world conditions vary from specific design and optimisation for the type-approval test to the limited robustness of the emission control technology for the circumstances encountered in the real-world tests. In the first case the technology will never work properly in the full spectrum real-world usage. In the second case improvements may be expected. For the petrol three-way catalyst it also took about ten years for the emission control strategy to mature to full robustness, which also copes with emissions during most hard accelerations.

Normal conditions of use as part of type-approval

European legislation already included a provision in 2007 to introduce on-road testing if the regulation based on type-approval tests in the laboratory proved insufficient to yield low real-world emissions, described in the legislation as “normal conditions of use”. In 2011 the European Commission started to develop real driving emissions (RDE) legislation because of the failure of Euro 5 cars and vans, sold from 2009 onwards, to reduce the on-road NO_x emissions of diesel vehicles.

The RDE legislation took a long time to develop because of the stakeholders’ involvement in the process. However, since 1 September 2017 all new vehicle models should be tested on-road. Since the manufacturer has freedom in the execution of the RDE test with the prototype vehicle, an essential ingredient of RDE legislation is to challenge the declaration of compliance of the manufacturer by doing independent testing in other, possibly more demanding conditions than chosen by the vehicle manufacturer in consultation with the type-approval authority. The change in the regulations on 1 September 2017 is not expected to yield significant change for some time as new vehicle models can be added to existing type-approvals. Only from 1 September 2019 will all new vehicles have to comply with the RDE regulation and RDE tests become unavoidable for manufacturers to sell new vehicles.

There is optimism that RDE legislation will deliver a substantial reduction in NO_x emissions and ensure real-world emissions consistent with the type-approval limits for the foreseeable future. But RDE legislation still lacks two important provisions. First, the final part of the RDE legislation, which covers challenges to RDE type-approval declarations of compliance, has yet to be finalised. Second, there is no provision for reform of European type-approval authorities, which is needed to make pan-European enforcement of vehicle emission legislation possible. Moreover, the finer details of the RDE legislation will determine how robust it is and this will only become apparent as it is implemented.

Impacts of driving conditions on emissions

Driving behaviour, congestion and speed limits can all affect the emissions of a vehicle significantly. For vehicles already in use, influencing driving conditions is one of the few means by which exhaust emissions can be reduced.

The problem with congestion is the low velocity and the high vehicle dynamic range (acceleration and braking). Below 50 km/h most emissions of a modern vehicle are associated with keeping the engine running, rather than propelling the vehicle forward. Below 50 km/h therefore, halving the velocity roughly doubles the emissions per kilometre. Simply said, the engine is operating twice as long if the velocity is halved. The second effect is the higher dynamics associated with congestion. A large number of stopping or braking events means that a larger part of the energy produced by the engine is not used for getting from origin to destination but is converted into heat in the brakes. The low velocity and the increased braking may double the emissions per kilometre in congested urban situations.

Hybrid vehicles are designed to deal more efficiently with the low velocity and high dynamics of congested traffic. In the case of hybrid vehicles the emissions do not increase as dramatically with increasing congestion.

Reducing congestion to reduce emissions is seldom simple. In many cases the bottlenecks in the traffic capacity of a road network are simply shifted in position rather than removed by measures to manage congestion. This will shift the source of the emissions to a new location. In some cases shifting the traffic congestion to another location is warranted, when it can reduce the actual exposure of citizens.

On the other end of the velocity range, above 90 km/h, engine power demand increases rapidly with speed because of the air-drag on the vehicle. From 100 km/h to 150 km/h the fuel consumption typically more than doubles, and given the limited optimisation of the emission control technology for high velocities the pollutant emissions will increase in many cases many times that amount. A factor of five or more increase in pollutant emissions is not exceptional for velocities above 100 km/h.

Altogether, for modern light-duty vehicles driving constantly between 50 km/h and 90 km/h will yield the lowest fuel consumption and the lowest pollutant emissions. In the Netherlands an 80 km/h speed limit on motorways was introduced for the beltways of Amsterdam and Rotterdam to reduce air-quality problems in the neighbourhoods within one kilometre of these motorways. Motorways have a large effect on local air quality due to the 100 000 or more vehicles that can pass per day.

Emission measurement and modelling

The measurement of real-world emissions had to shift from laboratory tests to on-road emission tests because of the elaborate vehicle emission control strategies. Even without an illegal defeat device, vehicles can have very different emissions in normal on-road conditions than in the laboratory. Hence in the assessment of the emissions performance of vehicles it is essential to replicate as well as possible the variety of normal conditions on the road. A shift from a simple test to monitoring of vehicle emissions over a longer time is important for grasping the effects over the full span of on-road conditions.

Since 2009 for heavy-duty vehicles and since 2011 for light-duty vehicles, on-road emissions measurements are part of the determination of the average vehicle emissions for in Dutch air quality models. The official emissions factor model, developed by TNO, is updated annually with the new measurement results from the previous year of emissions testing. Test results from at least ten different common vehicles in the same emissions class are needed to provide a confident prediction of emissions in a variety of circumstances, with as a rule of thumb, each vehicle undergoing at least a day of testing over about 600 km.

Impacts of malfunctioning and tampering

Occasionally a test vehicle performs very poorly because of malfunctioning, tampering, deterioration, or poor maintenance. It is difficult to point to a single factor responsible for high emissions from an older vehicle. Design, maintenance, usage and fuel quality all play a role. Hence, even with a large measurement program it is difficult to have cars banned from the road because of measured high emissions. The manufacturer will point to the user, who, in turn, will point to the garage undertaking maintenance. The garage will point to the annual inspection procedure and the inspection authority will point to the legislation. Eventually, nobody will have full responsibility for a poorly performing car. Unlike safety issues, emission performance seems hardly enforceable in Europe. Even in the aftermath of the scandal around diesel vehicles, and the common knowledge that certain vehicles have extremely high emissions, there has not been a backlash in enforcement. Basically, there is no proper legal framework to deal with violations of emission regulation.

The prohibition of the wilful removal of a diesel particulate filter, the use of inferior replacement parts, or the switching-off of the EGR or AdBlue injection of an SCR system, can be enforced. However, it requires good legislation to separate harmless adaptions of the vehicle from adaptions which increase emissions. Only a technically skilful enforcer can establish if a breach of the legislation has taken place. This is not a trivial matter as high punitive sanctions are needed to ensure the limited risk of detection yields sufficient deterrence. Measuring emissions reproducibly to establish with confidence a deviation, and its underlying cause, requires a professional inspection service. The typical emission limits in periodical inspections are factors higher than the emission limits in type approval tests.

Tampering exists in Europe, but the magnitude of the problem is largely unknown. There is no proper enforcement against tampering in place anywhere in Europe, unlike the US, where the EPA keeps a full record of the proper state of in-use vehicles, including certification and registration of replacement parts. The reasons for tampering are mainly cost related. The SCR is switched off to reduce the cost of AdBlue refills. Switching off the AdBlue injection is not completely trivial, because of the on-board diagnostics (OBD) control required by legislation. Likewise, the removal of a diesel particulate filter is not a simple procedure. However, drivers, who drive mainly in urban areas below 80 km/h, may encounter maintenance problems because of failed filter regeneration. Such regenerations should take place about every 500 kilometres and they require hot exhaust gas, produced typically with motorway driving. If a vehicle does not enter the motorway often enough, the filter will be clogged and the engine will stop working. Moreover, an uncontrolled regeneration may cause a vehicle fire. The expensive maintenance of clogged filters can be avoided by removing the filter, with high particulate emissions as a result.

Other forms of tampering are the closing off of clogged EGR that requires maintenance and the flashing of the engine control unit for more engine power, probably at the expense of high emissions. These two forms of tampering are usually done together as normal EGR control will not work in conjunction with the power increase.

Impact of real-world emission performance on the effectiveness of local air quality policies

Reducing vehicle emissions with local measures to improve air quality has turned out to be difficult. A decade of mitigation policies in Dutch cities to bring the ambient concentration levels below the European air quality limits has found no silver bullets but instead many demanding measures were implemented, each providing only a small positive reduction in emissions.

Many municipalities have introduced environmental zoning for traffic as a policy instrument for curbing local emissions and improving air quality. In Europe many low emission zones are enforced on the basis of vehicle emission legislation classes, banning older vehicles with higher legislative emission limits. These limits may have little to do with the on-road emission performance of the vehicle, but they can be properly registered and enforced.

The biggest hurdle is that vehicles, once allowed on the road, will be used for fifteen years or longer. Any measure affecting the sales of new cars will not be effective for ten years or longer, as the older vehicles dominate total emissions. The scrappage of older vehicles is usually not very cost effective as a large number of older vehicles, each driven only a limited annual mileage, are together responsible for the high emissions. The replacement vehicle in scrappage schemes may also not bring much improvement. Measures on public transport buses, including fleet renewal or the introduction of alterative propulsion technologies, are often most effective, as these vehicles drive a high mileage in areas where air quality is an issue.

Bringing the velocity of vehicles to a constant 50 to 90 km/h, at least on motorways, is the best alternative that does not affect personal mobility negatively. Expanding the infrastructure capacity to reduce congestion may yield a short-term benefit, but the increased road capacity will generally result in increased traffic volumes within a few years. Road pricing and parking pricing may provide more durable reductions in congestion.

The use of private cars is linked to personal freedom and economic activity. Hence the option to limit the daily mileage of vehicles to reduce the total emissions and improve the air quality is not usually available. Other measures have to be taken to reduce the vehicle emissions. These measures come in four groups. The first measure is a long-term plan: stimulate new vehicles with clean technology possibly enhanced by scrapping the oldest vehicles with the largest impact on air-quality. Second, reduce vehicle use by stimulating clean public transport and alternatives like cycling. Third, enforce proper vehicle maintenance and prevention of tampering. Finally, reduce congestion and bring traffic velocities to a constant 50-90 km/h on motorways. A comprehensive package includes all four items, combined with campaigns to generate public awareness of their personal contribution to public health and quality of life.

Conclusions

The three-way catalyst, introduced around 1990, has reduced the emissions of petrol vehicles to negligible levels compared to diesel vehicles. The widespread application of DPFs from 2009 onwards has reduced particulate emissions of diesels to extremely low levels, well below the emission limits.

Nevertheless real-world pollutant emissions of road vehicles are often significantly higher than the type approval values. This is especially the case for NO_x emissions from diesels. Between Euro 1 and Euro 5 standards the European NO_x limit has decreased by a factor of five but real-world NO_x emissions have remained more or less constant.

High real-world NO_x emissions from light- and heavy-duty diesels are the main cause of high NO_2 concentrations in cities. The fact that newer light-duty vehicles are not significantly cleaner than older Euro classes reduces the effectiveness of local policy measures, like low-emission zones, to reduce the NO_x emissions of traffic. Some Euro 6 vehicles now show real-world NO_x emissions closer to the limit, but many vehicle models in real-world still exceed the limit by a factor of eight.

Given the fleet of vehicles on the road, implementing traffic measures that bring speeds to a more constant 50 to 90 km/h on motorways and ring roads is the most effective measure available to lower tiers of governments for reducing traffic emissions.

Annex 1.

TNO has undertaken emission testing for the Dutch government continuously since the 1980's. There are comprehensive programmes to test passenger cars, vans, trucks, buses and two-wheelers. The main purpose of the measurement programmes is to determine the on-road, in-use emission performance of vehicles relevant to Dutch air quality.[16] The emissions factors for different road types and congestion levels are updated annually on the basis of new measurement results. The reports and the results are available on-line. The table below summarises the main results for NO_x and exhaust PM emissions (particulate mass).

Table A1. **Main results of NO_x and exhaust PM emissions**

			Urban congested		**Urban normal**		**Rural**		**Motorway**	
		Component	**NOx**	**Particulates (PM1)**	**NOx**	**Particulates (PM1)**	**NOx**	**Particulates (PM1)**	**NOx**	**Particulates (PM1)**
		Legislation	[g/km]	[g/km]	[g/km]	[g/km]	[g/km]	[g/km]	[g/km]	[g/km]
Passenger cars	Petrol	Euro-1	1.29	0.108	0.72	0.067	0.47	0.0068	0.25	0.0025
		Euro-2	0.69	0.0046	0.47	0.0046	0.21	0.0023	0.20	0.0050
		Euro-3	0.21	0.0046	0.15	0.0046	0.059	0.0023	0.036	0.0050
		Euro-4	0.079	0.0046	0.054	0.0046	0.025	0.0023	0.015	0.0050
		Euro-5	0.063	0.0037	0.043	0.0037	0.020	0.0019	0.012	0.0050
		Euro-6	0.063	0.0037	0.043	0.0037	0.020	0.0019	0.012	0.0050
	Diesel	Euro-1	1.92	0.372	1.06	0.236	0.45	0.101	0.69	0.081
		Euro-2	1.10	0.162	0.80	0.111	0.55	0.045	0.67	0.092
		Euro-3	1.23	0.043	0.80	0.031	0.55	0.026	0.70	0.052
		Euro-4	0.69	0.051	0.43	0.033	0.38	0.016	0.51	0.035
		Euro-5	1.00	0.0005	0.67	0.0005	0.53	0.0005	0.59	0.0015
		Euro-6	0.55	0.0005	0.43	0.0005	0.34	0.0005	0.41	0.0015
		Euro-6 RDE	0.31	0.0005	0.23	0.0005	0.17	0.0005	0.17	0.0015
Trucks	Light	pre-Euro	12.4	0.971	7.7	0.54	6.4	0.3273	7.0	0.27
		Euro-1	8.1	0.477	5.0	0.26	4.2	0.1588	4.5	0.13
		Euro-2	8.7	0.192	5.4	0.107	4.4	0.0771	4.6	0.067
		Euro-3	10.3	0.224	5.7	0.124	3.9	0.0747	4.2	0.054
		Euro-4	10.1	0.046	6.3	0.025	3.3	0.0138	3.3	0.0102
		Euro-5	7.4	0.016	4.6	0.0099	2.8	0.0066	1.7	0.0055
		Euro-5 with OBD	7.5	0.014	4.7	0.0087	2.7	0.0057	1.8	0.0048
		Euro-6	0.44	0.010	0.28	0.0061	0.19	0.0042	0.17	0.0037

Table A1. **Main results of NO_x and exhaust PM emissions (continued)**

		Component	Urban congested		Urban normal		Rural		Motorway	
			NOx	**Particulates (PM1)**	**NOx**	**Particulates (PM1)**	**NOx**	**Particulates (PM1)**	**NOx**	**Particulates (PM1)**
		Legislation	[g/km]	[g/km]	[g/km]	[g/km]	[g/km]	[g/km]	[g/km]	[g/km]
Trucks	Heavy	pre-Euro	33.6	2.49	21.0	1.38	15.0	0.82	13.3	0.63
		Euro-1	22.1	1.29	13.8	0.72	9.9	0.41	8.5	0.32
		Euro-2	23.3	0.56	14.6	0.31	10.2	0.19	8.8	0.16
		Euro-3	28.0	0.55	15.6	0.30	9.4	0.17	8.3	0.13
		Euro-4	24.1	0.110	15.1	0.061	7.9	0.031	7.9	0.023
		Euro-5	18.8	0.044	11.7	0.028	6.6	0.021	3.9	0.0162
		Euro-5 with OBD	16.3	0.041	10.2	0.026	5.6	0.017	3.7	0.0131
		Euro-6	1.37	0.030	0.86	0.019	0.56	0.012	0.46	0.0101
Busses		pre-Euro	27.0	2.10	16.9	1.13	12.4	0.65	11.3	0.50
		Euro-1	21.6	0.90	13.5	0.48	9.0	0.31	6.3	0.22
		Euro-2	19.6	0.58	12.2	0.31	8.1	0.28	6.5	0.111
		Euro-3	17.2	0.43	10.8	0.23	6.3	0.19	4.4	0.109
		Euro-4	13.3	0.18	8.3	0.098	4.2	0.043	3.0	0.019
		Euro-5	7.18	0.153	4.5	0.075	2.3	0.051	1.6	0.051
		Euro-6	1.11	0.015	0.69	0.015	0.42	0.0091	0.33	0.007

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Notes

[1] [1] The Metropolitan Area of Valle de México is composed by Mexico City, 59 municipalities of the State of Mexico and one municipality from the State of Hidalgo, as defined by the National Population Council (CONAPO). Some of the principal environmental protection measures, such as the periodic motor vehicle inspection and maintenance programme, the *Hoy No Circula* system of restrictions on the use of vehicles and the air pollution alert plan are applied over a smaller area, defining the ZMVM as Mexico City and 18 municipalities of the State of Mexico.

[2] The US heavy-duty vehicle standards were set in 2007 with a phase in of stricter NO_x limits that became binding only in 2010. The standards are therefore generally referred to as EPA 2010 even if this is not strictly accurate.

[3] NO_x and PM control technologies on light duty diesel vehicles have also suffered performance problems in urban use, see Chapter 3.

[4] Under Euro 5 light-duty vehicle standards, gasoline cars were subject to a very low mass limit for particulate emissions, 5 mg/km. US Tier 2 and 3 regulations include a similar limit. Under Euro 6 standards the number of particles emitted per km is identical for gasoline and diesel cars. For heavy duty vehicles, particle numbers have been regulated since Euro VI regulations in 2013.

[5] As noted, the damage done by particulates depends on the metals and other toxic molecules attached to them. Particle filters with catalytic surfaces have been developed, notably for use in heavy equipment for tunnelling, which can strip off many toxic contaminants and offer a more effective approach to controlling particulate emissions in the future. Such filters are available for retrofit on any heavy vehicle and have been installed for example on buses in Madrid and Barcelona. This technology promises a more effective route to limiting emissions in all types of engine.

[6] Wikipaedia provides summarises requirements in a range of countries with reasonably up to date information: https://en.wikipedia.org/wiki/Vehicle_inspection
https://en.wikipedia.org/wiki/Vehicle_inspection_in_the_United_States

[7] The governing body is composed by Minister of Environment and Natural Resources, the Mayor of Mexico City and the Governors of the States of Hidalgo, Mexico, Morelos, Puebla, and Tlaxcala (…).

[8] Available at http://www.aire.cdmx.gob.mx/default.php?ref=Ym-Q=

[9] Ultraviolet (NO_x) and infrared (CO, CO_2, HC) laser light absorption sampling of exhaust plumes as cars drive by sensors installed at the roadside.

[10] The Emission Reduction Comprehensive Program (PIREC) works through two main mechanisms: free substitution of catalytic converters for vehicles that are over 15 years old, and for more recent models that have declared failures on their catalytic converters during vehicle verification tests.

[11] Atizapán de Zaragoza, Cuautitlán, Chalco, Ecatepec de Morelos, Naucalpan de Juárez, Chicoloapan, Tecámac, Tultitlán, Cuautitlán Izcalli, Chimalhuacán, Huixquilucan, La Paz, Nezahualcóyotl, Nicolás Romero, Tlalnepantla de Baz y Valle de Chalco.

[12] The Megalopolis region is comprised by 12 metropolitan areas: Mexico City, Puebla-Tlaxcala, Toluca, Cuernavaca, Pachuca, Tlaxcala-Apizaco, Cuautla, Tehuacán, Tulancingo, Tula, Tianguistenco and Teziutlán.

[13] It is important to remark that this payment is substantial enough to be used in exceptions, such as emergencies or when a vehicle has to access on a seldom fashion. If the payment amount is designed as an incentive to be granted access, but a considerable number of units opt for paying it, we would stand before a congestion charge scheme and not a low emission zone.

[14] The selection of these low emission zones is based on their representativeness, but it is primarily based on their relevance as better practice studies. Stockholm was the first LEZ implemented in Europe, so there has been a considerable amount of time to study its effects. London is possibly the most know LEZ and the most studied one. Berlin represents the increasing number of German cities that are implementing these zones. Finally, Milan is a case of regional implementation that has a relatively different scheme, compared to more known LEZs across Europe.

[15] For more information and reports see:
https://www.tno.nl/en/focus-areas/urbanisation/mobility-logistics/clean-mobility/emissions-of-nitrogen-oxides-of-diesel-vehicles/
https://www.tno.nl/en/about-tno/dossiers-in-the-news/real-world-vehicle-emissions/
https://www.tno.nl/en/focus-areas/urbanisation/mobility-logistics/clean-mobility/measuring-the-emissions-of-passenger-cars-and-vans/
https://www.tno.nl/en/focus-areas/urbanisation/mobility-logistics/clean-mobility/measuring-the-emissions-of-trucks-and-buses/
https://www.tno.nl/en/focus-areas/urbanisation/mobility-logistics/clean-mobility/emissions-of-particulate-matter-from-diesel-cars/
https://www.tno.nl/en/focus-areas/urbanisation/mobility-logistics/clean-mobility/emission-factors-for-road-traffic/
http://www.ermes-group.eu/web/reports_and_publications

[16] The Dutch national emission inventory can be found at:
http://www.emissieregistratie.nl/erpubliek/bumper.en.aspx
For Europe the European Environmental Agency keeps track of the state of affairs, collecting the data from the member states: http://www.eea.europa.eu/

Strategies for Mitigating Air Pollution in Mexico City

International best practice

This report examines air pollution mitigation strategies in Mexico City. It identifies a series of measures that can strengthen current approaches to air pollution mitigation adopted in Mexico's capital as well as nationally. Recommendations include actions in policy areas such as emissions standards and testing, incentives for cleaner vehicles, fuel quality, inspection and maintenance, restrictions on vehicle use, parking regulation and speed limits, air quality plans, enhancement and promotion of sustainable transport modes as well as improving enforcement and public communication. The publication assembles the findings of a workshop organised by the International Transport Forum (ITF) and the Development Bank for Latin America (CAF) together with the Ministry of Environment of Mexico City (SEDEMA) in January 2017.

This report is part of the International Transport Forum's Case-Specific Policy Analysis series. These are topical studies on specific issues carried out by the ITF in agreement with local institutions.

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2017-04/Photo credit: Mexico City on a clear day, SEDEMA/Enrique Abe