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Low Emissions Zones (LEZ) in Mexico:

Recommended Essentials for LEZ Schemes in the Mexican Megalopolis Region

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Executive summary

Mexico is implementing an encompassing set of climate policies: It adopted in 2012 its General Climate Change Law 2012 followed by the National Climate Change Strategy 2013 that defines strategic axes for 10, 20 and 40 years, and the Special Program on Climate Change 2014-2018 (PECC II) that defines specific activities and measures. It is currently in the process of ratifying its (Intended) Nationally Determined Contribution (NDC),that foresees commitments of -22% GHG and - 51% Black Carbon mitigation (-36% GHG and –70% Black Carbon conditional upon international support) until 2030 compared to Business as Usual, complemented by adaptation measures.

With a share of 22% the road transport sector is the biggest and fastest growing source for greenhouse gas (GHG) emissions in Mexico (National Emissions Inventory 2013). The Mexican government has shown commitment in reducing GHG emissions from the transport sector and has included the sector in many initiatives, policies and measures. Both the Climate Change Programme PECC II and the NDC highlight the importance of the sector in contributing to mitigation objectives and include measures which aim to reduce GHG emissions from this sector by promoting sustainable mobility and urban transport (PECC II, Strategy 3.5). Low-Emissions-Zones (LEZ) are one of various important tools and instruments to reduce GHG emissions from the transport sector to significantly improve the air quality of cities and lead to various important co-benefits (improved public health, public living, etc.). LEZ are areas in which access is allowed only to vehicles that are low in pollution, and are an instrument widely implemented for example in Europe.

Although the road transport sector contributes to GHG emissions and poor air quality in all Mexican cities, these effects are particularly strong in the cities of the Megalopolis; i.e. the region around Mexico City which includes the states of Mexico City, State of Mexico, Morelos, Hidalgo, Tlaxcala and Puebla and has a population of around 30 million. LEZ would therefore have a significant impact in cities of this region.

Two cities of the Megalopolis already have presented implementation plans for so-called Ecozonas. Technical knowledge on the elements which ensure a successful LEZ, however, is limited as there are no precedents in the country nor on the continent.

This is where this study departs: It provides guidance for guidance for State or City authorities in the Mexican Megalopolis in their efforts to combat air pollution from road traffic by imposing access restrictions in polluted and populated city areas for vehicles not meeting certain emission criteria. Setting up such low emission zones (LEZ) in urban areas is a frequently applied recipe in European cities, where road transport is a major reason for non-compliance with the air quality standards for particulate matter (PM10 and PM2.5) and nitrogen oxides.

In order to help local authorities in Mexico in assessing whether and how LEZ could be a promising measure to curb pollutant emissions from road traffic, the paper here briefly describes the different features of European LEZ schemes, their differences, communalities, their potential and their limitations with regard to reducing air pollutant emissions from road transport.

The Governments of the State of Morelos and of the State of Mexico already introduced so-called *Ecozonas* in relatively small downtown areas of their capital cities Cuernavaca and Toluca, serving multiple policy goals, like traffic calming, sustainable mobility, recovery of public space, etc. Unlike a LEZ, the *Ecozona* is not specifically designed to improve the pollutant emission performance of the remaining vehicle fleet cruising around in these urban areas. Cleaning up the vehicle fleet faster than it would happen through normal progress in vehicle technology was indeed the reason for many European cities to put in force LEZ schemes with access restrictions for vehicles with high pollutant emissions in order to curb pollutant emissions from road transport and to avoid excess of air quality standards.

So, Low Emission Zones (LEZ) should be considered as complementary with the *Ecozona concepts*, in order to ensure a tangible reduction of pollutant emissions from road traffic and significant improvements of the air quality in the Megalopolis cities.

Taking into account the different boundary conditions in Mexico in relation to Europe, like the lack of Diesel cars, high share of old vehicles and differing socio-economic conditions, the report offers recommendations for the essential aspects and steps to be accounted for when introducing and practically implementing LEZ schemes in the Mexican metropolis.

Recommended essentials for the design and implementation of LEZ schemes in the Mexican Megalopolis can be summarised as follows:

Area of the LEZ

The LEZ area should cover the area with busy town centres, hubs of public transport, business and shopping centres and most densely populated areas in a city, where pollution is most severe. It should be large enough so that the zone cannot easily be bypassed. As a rule of thumb the LEZ should cover an area where 30% or more of the population of the whole city live.

Type of vehicles

Emission-based requirements for access to a LEZ should be set for all road vehicles with 4 wheels. Retrofit of closed loop catalytic converters and diesel particulate filters (DPF) should be allowed to qualify for compliance with the LEZ requirements.

LEZ operation time

The LEZ access restriction should be durable, rather than only during pollution episodes, every second day or even only once a week as required by the "hoy no circula" scheme in Mexico City. While the latter promotes purchase of second cars, leads to a shift of car trips into periods with free access and therefore dilutes the emission savings effect, a durable operation, preceded by a sufficiently long pre-warning phase, is easier to sell to the public and results in a stronger modernization of the vehicle fleet.

Emission requirements and phased introduction of LEZ schemes

It is recommended to take the existing Hologram scheme of the Mandatory Vehicle Inspection Program, PVVO, as a starting point for setting emission requirements to be met for vehicles in LEZ schemes in the Mexican Megalopolis.

Before LEZ requirements are defined on the basis of the Hologram categories, the current Hologram scheme needs to be revised to account for improvements in vehicle and

emission monitoring technology, in particular the opacity limit, Diesel vehicles must not exceed during the emission testing.

The Hologram scheme should reward investments into better emission control technologies by allowing an upgrade to a better Hologram category for vehicles retrofitted with a catalytic converter or a DPF.
Table 1 in the report presents a proposal for updated emission limits for the Hologram scheme of the PVVO.

All DPF systems and catalytic converters allowed for retrofit in Mexico should need to be certified, based on already existing international certification standards, so that they meet the same technical features, especially filter efficiency and durability criteria.

Introducing a LEZ scheme in several phases should be the preferred way forward as this allows the worst polluting vehicles to be removed in the first phase and the population to get used to the LEZ concept. This means starting with a weaker emissions standard which is then tightened after a period of time.

Table in the report presents a proposal for a phased way of introducing durable LEZ schemes in the Megalopolis. As taxis and local buses are part of the public transport system, which should be an attractive and less polluting alternative to private car use, stricter requirements are proposed for these kinds of vehicles. For ordinary vehicles stage I requires hologram 1 as a minimum. If the upgrade option will be enshrined in the hologram scheme as recommended above, category 1 would also allow access of vehicles, which initially belonged to a lower hologram category, but qualified for an upgrade, because they were retrofitted with an efficient catalytic converter or a DPF, meeting the emission limits of hologram 1.

Assuming implementation of the proposed LEZ scheme plus complimentary measures, such as funding for scrapping old vehicles and for retrofits and exemptions limited to genuine cases of hardship, about 2 years transition phase should be allowed between the formal adoption of the LEZ concept after a public consultation phase and the start of the access restriction in practice. A similar time period is considered appropriate between stage I and II.

Exemptions from the access restriction of the LEZ

Individual exemptions should be granted very thrifty, in combination with a longer transition period for the introduction of the LEZ.

Apart from general exemptions for emergency vehicles, historic vehicles and vehicles for diplomatic and military transport, individual exemptions should be possible upon application under certain conditions that is a severe hardship, because neither (i) an alternative means of transport nor (ii) the financial means for purchasing a LEZ-compliant vehicle are available. As a general principle exemptions should only be allowed for vehicles, which cannot be retrofitted with a relatively cheap catalytic converter (Otto-engine) or a DPF (diesel engine) and therefore not be upgraded to a better hologram category required to drive in the LEZ. As (i) mostly applies to commercial vehicles, conditions for exemptions granted to companies, in particular to small businesses with poor financial resources, should be less strict than exceptions for private car use, where public transport and cycling could be seen as an acceptable alternative, unless car users

are nightshift workers or handicapped with mobility problems. Applications for exemptions should only be approved, if compliance with the said conditions can be demonstrated by appropriate documents. Exemptions should not be released for free, but rather at a charge somehow linked to the value of the exemption that is the saving due to the allowed suspension of the investment into cleaner vehicle until the exemption will expire.

Validity of exemptions should be limited (e.g. two years maximum) and fees related to its duration and the size of the vehicle. In order to avoid corruption, it is paramount that the release and approval of exemptions is limited exclusively to public authorities.

Given the relevance that the public bus transport system and the taxi fleet have on the personal exposure of a great amount of people, exemptions shall not be granted under any circumstances.

The basic principles of the exemption scheme should be laid down in the regulatory LEZ framework underpinning the LEZ in a harmonized way for the whole Megalopolis region.

Vehicle identification and enforcement

Manual enforcement by the police and/or traffic wardens is considered best for the circumstances in the Megalopolis. The enforcement should be sufficient to deter non-compliance and achieve fairness for those who comply. There should be regular controls and strict enforcement by imposing fines for non-compliant vehicles without the requisite hologram in the LEZ. Sufficient educated personnel for police and traffic wardens needs to be provided to ensure sufficient surveillance of vehicles entering the LEZ.

Economic incentives

Financial support for vehicle owners of non-compliant vehicles, in particular of small businesses, can considerably mitigate resistance and help in the acceptance of the LEZ. So, funding for retrofits of DPF and catalysts should be provided, covering about 50% of the retrofit costs. Depending on the available financial resources, a scrapping bonus limited to the oldest and most polluting part of the vehicle fleet (e.g. older than 20 years) should be considered.

As a complimentary measure an emission dependent charging element should be incorporate in the existing motorway toll system, favouring clean trucks, especially those equipped or retrofitted with a DPF or running on natural gas.

LEZ Impact assessment

A thorough ex-ante and ex-post impact assessment study of the LEZ should be conducted in order to get sufficient support by the public and important stakeholders. In order to be more convincing to the public, benefits for public health should be estimated, if possible, based on the anticipated air quality improvements and on internationally accepted dose-response relationships between pollutant exposure and health impact. As a minimum, the impact assessment should consist of the fleet composition in terms of emission category ("hologram") per vehicle type, an assessment of the traffic volumes in and around the LEZ as an input for emission calculation for major road sections and of air quality monitoring especially at road side spots with heavy traffic, were changes of the vehicle fleet and/or traffic volumes are expected.

As an option, air quality street canyon modelling could be done in collaboration with research institutions or universities.

Public information and stakeholder involvement

Before planning the details of a LEZ scheme and prior to its implementation, public information and stakeholder involvement is important, because a LEZ access restriction does affect virtually every business and resident within the zone and adjacent areas and so will enhance acceptance of the LEZ plans.

Stakeholder involvement already during the drafting and preparatory phase of the LEZ development is particularly advisable with regard to transport businesses, firms and companies located in the LEZ area, e.g. by organizing workshops with business associations where the draft LEZ concepts would be presented and information on the specific needs of companies affected by the LEZ could be taken up. During the operation of the LEZ it is equally important to provide information in order to ensure the continuous effectiveness of the LEZ.

Regulatory framework and collaboration between different administrations

A LEZ needs to be based on a robust regulatory framework, which consists of a LEZ regulation determining the key rules, plus administrative instructions describing the details so that the responsible authorities implement and enforce these rules in an efficient and consistent way. The regulatory framework should set out in particular the details of the LEZ emission requirements, the permitted exemptions, effective penalties for violations the division of competence for LEZ controls between different authorities and details of financing of the necessary resources and economic incentives.

It is strongly recommended to harmonize the regulatory framework as much as possible among the Federal States and cities, especially for emission requirements, exemptions and funding schemes, in order not to spark a competition among neighbouring LEZ cities for the most lenient approach.

Careful planning and successful implementation of a LEZ scheme is a complex interdisciplinary project requiring sufficient resources of experienced personnel. The risk of failure should be minimised by allocating extra personnel resources to the management of the LEZ project.

In order to ensure a close and mutually supportive collaboration between different parts of the administration, a LEZ steering group on political level and an internal LEZ project group on technical level should be set up during the planning and implementation phase of the LEZ.

Complementary measures

Any LEZ concept should be embedded into a larger urban development strategy to achieve the objective of improving the environmental situation and the living conditions in the city. In that sense the LEZ is perfectly compatible with and complementary with additional traffic calming concepts, like the *Ecozona* in Cuernavaca, which inter alia aims to reduce motor traffic in the city centre, while the LEZ will ensure that the remaining, unavoidable road traffic will be managed in a less polluting way.

Green public procurement is another important measure complementary to the LEZ, especially regarding municipal vehicle fleets. Establishing clean vehicle purchasing standards for all municipal departments and contractors can make a significant contribution to the urban vehicle emission reduction and at the same time promote cleaner vehicles to the private sector.

1. Introduction and objectives of this report

1.1 Context

Like in most countries in the world road transport in Mexico contributes considerably to greenhouse gas emissions in the country and to poor air quality in cities, in particular in the Megalopolis (Mexico City, the Federal States of Mexico, Hidalgo, Morelos, Puebla and Tlaxcala).

Given the rapid growth of the road transport sector, the Mexican government is increasingly focusing on measures to curb pollutant emissions of motor vehicles. In that context, the idea of setting up Low Emission Zones (LEZ) with access restrictions for vehicles with high pollutant emissions is considered as a promising way to accelerate the turnover of the vehicle fleet towards cleaner and more fuel efficient vehicles, supplemented by a stronger promotion of green transport modes.

The Governments of the State of Morelos and of the State of Mexico already announced the introduction of so-called *Ecozonas* in relatively small downtown areas of their capital cities Cuernavaca and Toluca. While the *Ecozona* concept is serving multiple policy goals, like traffic calming, sustainable mobility, recovery of public space, preservation of cultural and natural heritage, recreation, improving urban climate and the development of the local urban economy, Unlike a LEZ, the *Ecozonas* are not specifically designed to improve the pollutant emission performance of the (remaining) vehicle fleet cruising around in these urban areas.

Cleaning up the vehicle fleet faster than it would happen through normal progress in vehicle technology was indeed the reason for many European cities to put in force LEZ schemes in order to curb pollutant emissions from road transport and to avoid excess of air quality standards. The experience gained in designing and practically implementing LEZ in the EU and particularly in Germany could be tapped to derive similar concepts for polluted urban areas in Mexico.

In order to help closing the knowledge gap on LEZ on the political as well as on the technical level in Mexico, external expert advice is provided within the framework of the Mexican-German Climate Alliance. This program, implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry of the Environment, Nature Conservation, Building and Nuclear Safety is supporting the Mexican government to implement selected strategies on climate change mitigation and adaptation, with a view towards key co-benefits, such as air quality at national, state and municipal level.

The advisory service aims at providing profound information on the features of LEZ to environment policy makers as well as to administrators and technical staff in charge of implementing air pollution control and climate change mitigation strategies in the Mexican Megalopolis.

1.2 Purpose of the report

This report should be seen as guidance for State or City authorities in the Mexican Megalopolis in their efforts to combat air pollution from road traffic by imposing access restrictions in polluted and populated city areas for vehicles not meeting certain emission criteria. Setting up LEZ in urban areas is a frequently applied recipe in European cities, where road transport is a major reason for non-compliance with the air quality standards for particulate matter (PM10 and PM2.5) and nitrogen oxides. While LEZ schemes are certainly not the sole solution for urban air quality problems, experience in Europe showed that LEZ schemes, if properly designed and well enforced, could make an important contribution to achieve full compliance with air quality standards.

One should therefore consider whether a LEZ concept could also help Mexican cities along with other traffic planning measures to mitigate their well-documented air pollution problems, at least in those towns where road transport is a major contributor.

In order to help local authorities in Mexico in this assessment, this paper briefly describes the different features of European LEZ schemes, their differences, communalities, their potential and their limitations with regard to reducing air pollutant emissions from road transport. Good practice examples will be highlighted without ignoring flaws and imperfections of the LEZ schemes implemented in the EU. Much of the information, data and features of European LEZ schemes presented in the following section can be found on the CLARS[1] web-platform, funded by the European Commission.

After a section addressing the different boundary conditions in Mexico in relation to Europe, the following chapter will provide recommendations of the essential aspects and steps to be accounted for when introducing and implementing LEZ schemes in the Mexican metropolis.

2. Low Emission Zones in Europe: A short overview

2.1 Common objectives of LEZ in the European context

Low emissions zones as implemented in Europe are to be seen as access restrictions to urban areas with air pollution problems for certain types of motor vehicles depending on their pollutant emissions. So, the main objective of LEZ was to mitigate the air pollution generated from motorized road traffic in order to achieve compliance with air quality standards, in particular in major roads were attainment is needed even at the curbside. Most LEZ did not aim at calming traffic in the first place, but rather exert pressure on motorists to invest into cleaner vehicles. At least in German LEZ timing and stringency of the emission requirements were balanced in order to allow motorists to substitute their vehicle with a cleaner one or to make it compliant by retrofitting emission control devices, like diesel soot filters or catalytic converters.

[1] **C**harging, **L**ow Emission Zones, other **A**ccess **R**egulation **S**chemes, http://urbanaccessregulations.eu/

In that sense LEZ differ from more general access restriction schemes, which specifically aim at reducing traffic volumes (e.g. keep heavy freight traffic out, pedestrianizing a town centre), fighting congestion or (like road charging systems) simply raising money for infrastructure investment. In some cases LEZ and general access restriction schemes are combined, like in London with the congestion charge focusing on a relatively small central heavily trafficked city area and the LEZ scheme for heavy vehicles covering whole Greater London.

In this paper LEZ are defined as urban areas where the most polluting vehicles are restricted from entering. Vehicles are either legally banned based on their emission levels, or in some cases charged an emission depending fee. More than 200 LEZ have been implemented in many cities in various EU Member States. The following sections give a short overview of the various LEZ schemes in Europe, structured along relevant aspects related to the planning and implementation of LEZ.

For more details on urban access restriction schemes and especially on LEZ in Europe, please consult the internet portal urbanaccessregulations.eu. Additional background information, including reference to guidance documents to European regional and municipal administrations is provided in Annex I.

2.2 Variants of European LEZ schemes

2.2.1 Types of restricted vehicles, emission requirements, charges and exemptions

In the way of exerting pressure on owners of polluting vehicles to clean them up, two main categories of LEZ can be distinguished in Europe:

- Most LEZ schemes **legally ban** vehicles not meeting a given emission standard from entering an area of a town (most LEZs).That means, in the event of non-compliance motorists are fined as if violating road traffic rules.

- A few LEZ **charge polluting vehicles** more than cleaner ones. Fees range from moderate levels of a few Euros (e.g. the Milan Ecopass) in order to gradually discourage drivers to enter the LEZ area to rather hefty charging of very high daily entrance fees (London, with a charge of 200 pounds per day for a heavy vehicle) that in practice appear as ban of polluting vehicles virtually forcing sudden investments into more efficient emission control technology.

With regard to the **restricted vehicle type** some LEZ focus only on heavy vehicles (London, Scandinavia), because heavier vehicles are mostly having Diesel engines, which release much more of the problematic pollutants, i.e. particulate matter and nitrogen oxides, than light vehicles running on petrol. Given the lower numbers combined with a high vehicle-specific emission rate, targeting heavy vehicles is generally more cost effective with regard to the enforcement of a LEZ.

However, affecting also lighter vehicle types will have more impact, particularly for NO2 and benzene concentrations. This is true in situations with many old vehicles without a

closed loop catalytic converter, like in Mexico, but also in most EU countries, including Germany, with a high share of more than 30% of Diesel cars, where passenger cars are also included in the LEZ scheme, generating about half of the emission reduction emerging from the LEZ. This may also be as drivers that rarely go by car into the city find it more cost effective to change to public transport than to change their vehicle or decide not to make the trip at all. However, change in traffic flows has in practice not been observed, although there is some very limited reporting in Munich that suggests fewer vehicles are registered in the city, but this cannot be directly attributed to the LEZ.

Covering cars is often a politically affected decision. In some countries including private cars would be very difficult. In others this is more feasible, like in Germany, where affecting all vehicles was seen as fairer by the transport industry.

It is important to take account of vehicle flows in the city. In some cities it may be that heavy goods vehicles are a small proportion of the vehicles travelling in the city. Affecting these vehicles has therefore less impact than including vans or cars.

Where cities or countries have an older bus fleet, bus-LEZs have been implemented. In these schemes there are mechanisms that can control bus emissions that do not affect the general vehicle fleet. However, public bus fleets are also regulated by setting environmental quality requirements in the contracts signed with or concessions issued to bus companies providing public transport services in a municipality.

LEZ emission requirements are almost always set out in national legal frameworks based on the European vehicle emission standards (e.g. Euro 4 in Germany). However, in some countries, in particular in Germany, local authorities can determine the ambition level of the scheme according to their local circumstances by choosing the appropriate emission conditions and the time-scale of their introduction.
The choice of emissions standard and vehicles chosen will affect the acceptability. As more people are affected, more resistance emerges.

Many European LEZ allow **retrofitting**. This can lower resistance or enable a stricter standard to be set than would be otherwise possible, as the cost of retrofitting is usually lower than replacing the vehicle.

If retrofitting is allowed, there are certification schemes for the filter systems, which need to be defined carefully, to ensure that the desired outcome is achieved.

Certifications for Diesel Particulate Filter (DPF) have been based on the Euro standards, to ensure that they comply with the EU internal market rules and therefore do not constitute a barrier to free trade within the EU. However, there are still some issues of DPF retrofit regulated differently among EU countries. One concerns the filter efficiency, which for so-called "full DPF" reach 95-99% PM filtration, while cheaper "partial DPFs" have around 50% filter efficiency and do not function as well for ultrafine particles and can release parts of the stored PM at a later time. While partial DPFs are not as good as full DPFs, if certified correctly, they should give the predicted emission reductions in urban conditions.

Another issue is the accumulation of NO2 in the exhaust gas generated by some DPF often platinum-coated, using passive, catalytic regeneration techniques. While some DPFs increase primary NO2 emissions, others do not. Some even reduce NO2.

As the Euro standards do not refer to NO2, neither have the early certification schemes. Such a gap in the DPF certification exists for example in Germany despite severe non-compliance problems with the NO2 air quality standard.

Ideally, for maximum impact on PM10 and NO2, LEZs would at least for heavy duty vehicles (HDVs) limit retrofitting to certified, full DPFs that do not increase primary NO2. Even though most DPF certifications have interpreted EU law to say that partial and NO2 - increasing DPFs must be allowed, the London, Danish and Italian certifications now restrict one or both of these.

The best certification scheme is the one for London, which requires full filters and a limit of 30% NO2 increase and is available for heavy goods vehicles and heavier vans.

The two certifications that certify DPFs for cars are the German and Italian certifications. Currently partial filters are the only real option for retrofitting cars, due to the higher costs of full filters. At least for Germany, retrofit certification schemes also exist for catalytic converters, setting out minimum requirements for conversion efficiency and durability of the systems.

A regulation[2] recently adopted under the United Nations Economic Commission for Europe (UN-ECE) setting minimum technical specifications for Retrofit Emission Control (REC) devices will gradually replace these national frameworks. As it covers all types of emission control technologies for retrofit of Diesel vehicles, the REC regulation may become a global template for national certification schemes.

Exemptions:
Exemptions from the access restriction can mitigate the burden on affected vehicle owners in the early stages of a LEZ. It has been used in Germany when the notice period (see Section 2.2.3) prior to the launch of the LEZ has been relatively short. Where there was a difficulty in the delivery of sufficient vehicles or retrofit in time for the start of the LEZ an additional time period was granted based upon the condition that a purchase contract for the retrofit was already shown.

National co-ordination of exemptions increases clarity, acceptability and administration. In Germany and the Netherlands there are national exemptions, plus local exemptions valid just for a particular town. In London there are no exemptions, because expensive day passes can be purchased. In Denmark there are national exemptions plus exempted local key roads.

[2] UN-ECE Regulation No. 132: Uniform provisions concerning the approval of Retrofit Emission Control devices (REC) for heavy duty vehicles, agricultural and forestry tractors and non-road mobile machinery equipped with compression ignition engines. Addendum 131 to the "Agreement Concerning the Adoption of Uniform Technical Prescriptions for (cont. page 13): Wheeled Vehicles, Equipment and Parts which can be Fitted and/or be Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of these Prescriptions". Web access: https://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/updates/R132e.pdf

'Hardship exemptions' are used in Germany and the Netherlands for those for whom complying with the LEZ would cause significant financial difficulties. These 'hardship exemptions' can be used to mitigate the potential socio-economic impact of the LEZ without reducing significantly its impact, if they are strictly implemented.

These are implemented as local exemptions for the specific town/city where the applicant lives or works and needs to access. Applicants must prove that retrofitting is not possible and that they cannot afford a replacement vehicle. Businesses have to prove that the vehicle is essential to their business, that they do not have the funds to replace the vehicle and that retrofitting is not possible and would risk the viability of their business.

For Germany, in the case of private individuals, conditions are generally stricter and limited to cases, where public transport can hardly be considered as a viable alternative. Berlin limits exemptions to private vehicles belonging to people working night shift or being disabled. In addition, applicants need to prove that they cannot afford to replace the vehicle and that retrofit is not possible. In the Netherlands the number of applications under the hardship clause (which prevents businesses experiencing serious financial problems due to the LEZs) is very limited. Likewise, issued exemptions in Berlin remained below 10% of the total number of vehicles affected by the LEZ.

Looking at the range of exemptions, it appears that in effect the LEZ is aimed at commuters, as these are the vehicle operators that are less likely to be able to get an exemption. However, in terms of pollution, it might be more effective to target heavier vehicles.

2.2.2 Size and delimitation of the LEZ area

The emissions standard, affected vehicles and the choice of the LEZ area need to work together to have a sufficient impact on air quality.

Areas covered by the European LEZs range from small towns with a population of 6300 to the LEZ covering the Greater London agglomeration and the LEZ in the larger Ruhr area of Germany stretching more than 100 km across several large cities.

The London feasibility study also investigated smaller London LEZs (central and inner ring roads) as well as a collection of single LEZs limited to centres of suburban and peripheral towns. The study found that these have not been effective in terms of air quality impact, and the several town centre LEZs have been difficult to communicate. The LEZ in the Ruhr area in Germany was initially a 'patchwork' of LEZs, but changed to a single LEZ covering the whole area. In Berlin vehicle fleet composition revealed that focusing on the densely populated core city area (80 km2) already made a sufficient impact.

It seems essential to cover at least the area with business hubs and most densely populated areas where pollution is most severe.

One issue raised by areas bordering the LEZ is the fear that the LEZ will make pollution worse in their area, as the dirtier vehicles will then travel there. Both London's feasibility study and more widespread experience, for example in Berlin, have shown that this not to the case as long as LEZ areas exceed a critical size in relation to the rest of the city, so

that driving around isn't an attractive option. In fact, neighbouring areas have improved air quality as many vehicles based just outside the LEZ will comply to enable access to the LEZ, and cleaner compliant vehicles will travel through that area to reach the LEZ.

A diluted LEZ impact in e.g. more rural areas further away from the LEZ, where the second hand vehicles are sold, or where large vehicle operators re-organise their fleet, could occur but has not been reported until now.

Often the LEZ covers the area over which the authority has power. Another boundary used is the air quality management area, or other natural and easily recognizable margins, like railway lines, rivers, etc. Where there is a relevant motorway-like ring road, this can also make a useful boundary, as it is easily identifiable and gives a good by-pass for non-compliant vehicles. The disadvantage of this boundary, however, is that the ring road may well be a highly polluted area itself and the emissions not be reduced as much if it is outside the LEZ. Unless being close to neighbouring residential areas, this might be acceptable.

2.2.3 Time-scale of introduction, LEZ operation time

Phased implementation is a good way to implement a LEZ, and has been used by most European countries. This means starting with a weaker emission standard which is then tightened after a period of time. This allows the worst polluting vehicles to be removed during the first phase and the population to get used to the LEZ concept. The later phases of the LEZ, with tighter emissions standards will have more impact on air quality as well as on the vehicle fleet operators.

As an example, the London LEZ was introduced in four phases. It affected increasingly smaller vehicles, starting in 2008 in phase 1 with lorries above 12 tons, and then gradually decreasing the weight of the affected vehicles down to vans as small as 1.2 tons within four years. At the same time the required emission standard was tightened from Euro 3 to 4. This also helped starting the LEZ by affecting fewer vehicles, therefore increasing the acceptability on implementation.

Vehicle operators need sufficient time to adapt to a LEZ scheme. So, a reasonable notice period should be given. This allows vehicle operators time, for example, to re-arrange their delivery vehicles, purchase a new or second hand complying vehicle, retrofit, or contract out some deliveries, and so can increase acceptability. There is no firm rule about how long the transition period needs to be. However, the more warning that can be given, the better.

London and Berlin could be considered examples of a timescale of a good practice for LEZ introduction. In both cities the draft concept was presented for public consultation lasting 6 to 12 months, after which the LEZ scheme was formally adopted. From the time of the 'go decision' it took between 2.5 to 3 years to implement the LEZ in London and Berlin. This included the time needed to take the legal steps, as well as the notice to operators. In the case of Berlin, the consultation process formally started in February 2005, the scheme was adopted in August 2005 and the LEZ started on 1st January 2008 with stage 1, followed by the 2nd stage with tightened emission requirements beginning 2010.

Where there has been a fairly short notice for the LEZ, there has often been an 'introductory phase' with more generous exemptions or by delaying enforcement in that drivers of vehicles that do not comply are given information leaflets as opposed to penalties.

In general, it can be said, that the more vehicles are affected by the respective access restriction criteria, the more adaptation time should be granted for vehicle owners. Experience in Europe shows that a longer transition period in combination with stricter requirements gains more acceptance than a short notice combined with rather lenient emission requirements, which might not yield much of the promised air quality improvement and therefore could compromise the usefulness of the whole concept.

As regards the operation time of the LEZ, most schemes are durably enforced. A few, like some LEZ schemes in Northern Italy restrict access only during day time hours on working days, while night time and weekends are not restricted. Some LEZ work only during winter time, when dispersion conditions and pollution load tend to be worst. Such time constraints were intended to allow poorer motorists to still enter the LEZ during time windows with less traffic, hence less emissions and lower pollution concentration, but it adds complexity and lowers the pressure to replace or retrofit polluting vehicles, eventually impairing the environmental benefit of the scheme on the long term.

2.2.4 Vehicle identification and Enforcement

Most European LEZs are manually enforced with windscreen stickers showing the emission standard or category (for retrofits) of the vehicle. They need to be obtained before entering the LEZ (for example in Germany and Sweden). Stickers can add to 'peer pressure' for vehicle operators to have the newest stickers, depending on the relevant culture.

The Danish and German LEZs set out the three manual enforcement methods:

- municipal inspectors when lorries are visiting a company
- town traffic wardens checking vehicles parked on the street
- police at routine roadside checks.

Both inspectors and traffic wardens can call on the police when needed.

A few LEZ have automatic enforcement with cameras. The Dutch LEZs started with manual enforcement, but are gradually moving to camera enforcement, resulting in increased compliance rates. London simply extended the camera-based number plate recognition system initially built up to enforce the congestion charge in the very city centre.

If LEZs are automatically enforced with cameras, the national vehicle database will or needs to have information for national vehicles. A database is also needed for those who retrofit their vehicles with a DPF or replacement engine.

Surveys in Berlin, 6 cities in the Ruhr area and Stuttgart have shown compliance rates of 95% to 99% for passenger cars and 85% to 93% for commercial vehicles (lorries and vans). It should be noted though, that cultural differences limit the representativeness of these figures.

Another distinction for most EU countries is whether the LEZs are under criminal or civil law. For example, all German traffic offences operate under administrative law, which tends to require manual enforcement with police and can enable penalties such as a point in the national drivers traffic penalty register. Using civil law tends to enable camera and traffic warden (or similar non-police staff) enforcement without stopping the traffic. Camera enforcement can achieve higher compliance rates but requires high investment and operation costs.

2.3 Costs and Environmental Benefits of LEZ schemes

2.3.1 Methods to estimate the impact of LEZ

There are three ways in which air quality impacts of European LEZ have been assessed, each with their pros and cons:

- **Air quality monitoring**: enables the 'actual impact' to be measured – but only at specific sites and mixed with other confounding effects, like changes in pollutant dispersion conditions, traffic volumes, emissions of other sources, etc.

- **Fleet composition**: the Euro standard and retrofitting of vehicles registered or observed travelling in the LEZ, compared with a 'business as usual' scenario or the national fleet can be assessed. This is the impact of the LEZ, which in turn leads to air quality improvements.

- **Air quality or emission modelling**: is weather-neutral and confounders can easily be blanked out, but relies on emission factors, on vehicle fleet composition data or estimations. Emission factors are estimates based on vehicle measurements and are a key uncertainty. For example, those of later Euro standard vehicles have barely been tested under conditions representative for real world driving. The anticipated reduction in emissions from the Euro standard is not necessarily always delivered in real-life urban driving conditions. This is particularly true for Diesel cars.

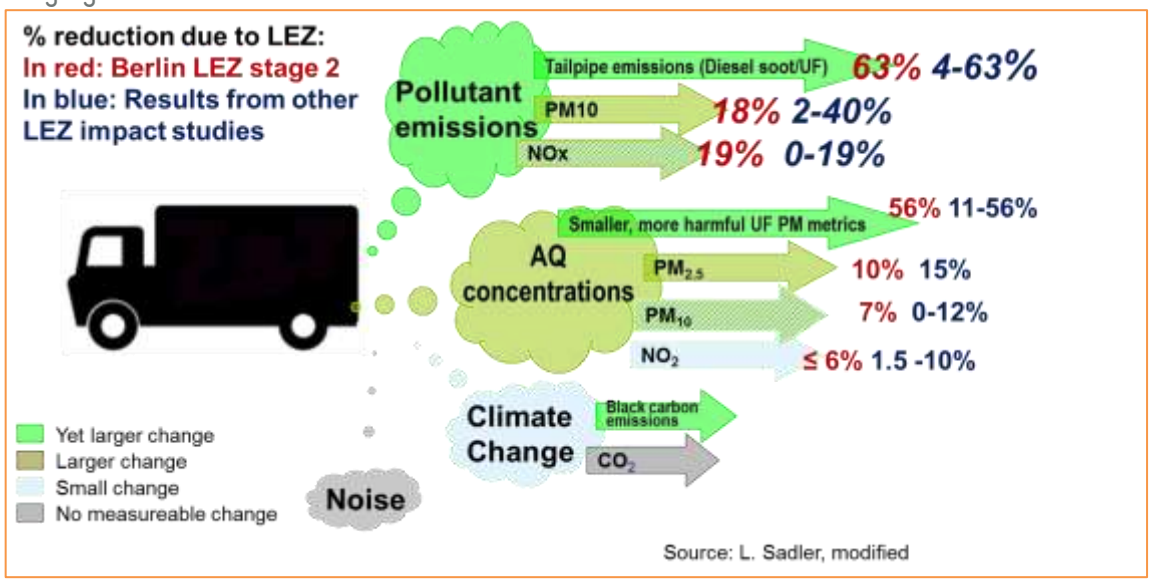
2.3.2 Results of impact assessment studies of LEZ in Europe

Reduction of diesel particulates which is only reflected in a few of the impact assessments, has a more significant health impact than for total PM10 and PM2.5. PM2.5, particulate number and black carbon will all be more affected by LEZs than PM10 due to the higher proportion of exhaust emissions, as well as having a higher health impact – which is why they have been assessed. Black carbon also has a climate change impact. PM10 and PM2.5 concentrations are more affected by regional concentrations than NO2, particle number or black carbon.

Noise, traffic reduction and CO2 have not been reported as changing significantly with LEZs. Traffic reduction is more likely to occur for LEZs aimed at cars, but in practice traffic reduction has not been observed. The main exception is the Milan combined

congestion charge-LEZ, which aims to reduce both traffic and pollution and therefore has had these two impacts.

The following schematic summarizes the reduction potential of LEZ under European conditions when covering all vehicles, including vans and passenger cars. It should be noted that the share of Diesel vehicles among cars and light goods vehicles is significant, ranging between 20 and 50% across EU Member States.



Summary[3] of the pollution reduction potential of LEZ in Europe

2.3.3 Implementation, enforcement and compliance costs of LEZ

LEZ costs can be split into four aspects:

- Costs to the authority to implement and operate
- Costs to vehicle operators to adapt to the LEZ
- Costs and benefits to society, e.g. health benefits and economic impacts
- Costs of any complementary measures.

The few cost estimates given below do not include the costs of setting up the national or regional regulatory frameworks. A national framework will reduce rather than increase costs, due to issues needing to be resolved for each city and the difficulty of doing this without national support.

In terms of income from LEZ fines, in Germany the income from the penalties go into the general town funds, which is also where the enforcement costs are paid from. In the Netherlands, the LEZ fines go to the National Treasury, not to the towns.

The costs to implement and operate a LEZ will depend on a number of variables, such as:

- whether manual or automatic enforcement is chosen;
- the fact, that all vehicles or just heavy duty vehicles are included;

[3] Source: Lucy Sadler, http://urbanaccessregulations.eu/, modified

- the size of the zone;
- or if it is combined with congestion charging, barrier controlled entry or other traffic management scheme.

Camera enforcement is generally more expensive to set up, but can be cheaper to run. With manual enforcement, running costs depend on the frequency of control, how police are funded and how much can be built into already existing traffic enforcement. The better the enforcement is managed, the greater the air quality impact is.

Concrete data and estimations of the implementation and enforcement costs are rare. Experience from the Netherlands indicates that implementation costs with manual enforcement for an average sized city (population around 200,000) is around €100,000, with annual enforcement costs around €75,000, increasing for larger cities. Set-up of camera enforcement was around €10-50,000.

Given the significant difference in costs for personnel between Europe and Mexico these figures are only a rough indicator.

Berlin's manual LEZ enforcement on the road did not generate extra costs. As the traffic wardens and the personnel of the local public order offices controlling parked vehicles as well as the police staff surveilling road traffic were checking the LEZ stickers on window screens during their normal job, staff resources were not increased. Extra personnel were detached to support the local public order offices in their task to handle the applications for exemptions from the LEZ. As exemptions were granted for a limited period the additional demand for staff was met by temporarily recruiting officers from other parts of the city administration.

As regards the burden for motorists and commercial vehicle fleet operators, prior to implementation the business community in the Netherlands and Germany exaggerated the (negative) impact that the LEZs would have, compared to that observed. German businesses claimed that many companies would go out of business, shop turnover would reduce, 1000's of job losses etc. Since implementation the business communities have confirmed that there has been no measurable impact. In Berlin the tourist board had also not noticed a negative impact on the numbers of overnight stays, contrary to what was alleged by the hoteliers association.

In the Netherlands LEZ cities have not received complaints from specific groups that they were disproportionately affected by the LEZ. In addition, the number of applications under the hardship clause, which prevents businesses experiencing serious financial problems due to the LEZs, was very limited. The same is true for Berlin, where the number of exemptions maintained below 10% of the number of registered vehicles not meeting the LEZ criteria. The LEZ had no noticeable impact on business of shops also in Mannheim, as confirmed by the local business community. In Gothenburg (Sweden), however, there were examples of companies without the financial resources to comply, which had closed down. But a Gothenburg haulier and supplier survey found that only 20% of respondents had a negative 'overall rating' for the LEZ, with 21% being very good, 28% fairly good, 24% neutral, 7% no response. The LEZ hit mostly companies that had not previously undertaken any environmental work and improved the competitiveness of those who had.

A complete cost-benefit analysis of LEZ, i.e. a full account of all costs compared to monetized health benefits emerging from the pollution reduction has rarely been done. Here are two examples from London and Berlin:

As regards the health impact of the London LEZ, it is estimated that, despite of the small absolute reduction of PM and NO2-concentrations (below 1 µg/m³) 5200 years of life could be gained and 43 respiratory and cardiovascular hospital admissions avoided. These resulted in £200 million discounted benefits after subtraction of the costs.

For Berlin a rough cost benefit spreadsheet calculation revealed costs to vehicle operators between 150 and 450 Mio, which include

- DPF retrofit costs for 60.000 Diesel vehicles (about 20% of the total Diesel fleet), assuming 1000€ per passenger car and 6000 € for a lorry or truck
- Costs for the sticker for every vehicle (5€)
- Costs for substituting non-compliant vehicles by cleaner ones

The cost range above depends on whether to account for the full costs of purchasing a new vehicle or whether to allocate only a fraction (e.g. 10%) to the LEZ and the emerging need to scrap an older and polluting vehicle. In practice, the renewal of the vehicle fleet should not be fully linked to the LEZ, because older vehicles would have been substituted sooner or later anyway. Even if the upper cost margin is taken, benefits calculated from the positive health impact always exceed the costs by a factor of 2 to 4. More than 400 premature deaths can be avoided or 16.000 life years saved, worth of more than 800 Mio Euros.

2.4 Supplementary measures to increase acceptance

Acceptance of LEZs can be significantly assisted if they are supported by complimentary measures. These are examples of additional efforts taken by LEZ cities:

- Leading by example, in that the public sector, including the public bus fleet, strongly invests in cleaner vehicles, in order to fully meet or even exceed the LEZ requirements.
- Early information and stakeholder involvement, in order to allow vehicle owners, in particular operator of commercial fleets, to early plan investments in retrofitting or replacing non-compliant vehicles.
- grants or cheap loans to retrofit or replace vehicles, in order to ease the financial burden, especially to small businesses
- improved public transport if the LEZ affects private cars, and improved freight logistics for hauliers
- Exemptions in case of hardship, used carefully so as not to significantly reduce the impact of the LEZ.

2.4.1 Information and participation of stakeholders and the public

The knowledge or acceptance, that there is an air quality problem is a very useful aspect in acceptability of any air quality action. This makes action particularly in larger, accepted-as-polluted cities easier.

Good public understanding is essential to acceptance. In a number of countries there have been air pollution campaigns, raising the issue of air pollution. One example is ATE (Association Transports et Environnement) in Switzerland, with 'a filter in the town', and their PM10.ch website, with regularly changing campaigns and their lung logo. In the UK the recent re-estimating (and significant increase) of the number of people estimated to be killed by air pollution has increased public discussion and concern about air pollution. Consultation on the LEZ before a formal decision to implement it can be part of this increasing public understanding.

In the Netherlands (lorries only), they agreed the LEZs in a working group that included the national and local Governments and the Dutch main haulage organisations. For the hauliers, the agreement included significant grants for retrofitting for the Dutch fleet, implementation of improved logistic schemes in LEZ towns, an assessment protocol that is needed before implementation of a LEZ, and that LEZs are only in urban areas and e.g. not single roads to industrial estates.

In Germany (all vehicles except 2-wheelers) the political reaction has been mixed. Air quality measures are decided by the Federal States, usually planned out by the district authorities and then implemented by the cities. This has sometimes been a cause for disagreements. For example Munich wanted to implement a LEZ, while the Federal State of Bavaria, did not want to. It was only after a legal challenge from a Munich resident that Munich was allowed to implement a LEZ. Vice versa, in Freiburg-im-Breisgau the LEZ was required to be implemented by the Federal State (Baden-Württemberg) against the wishes of the Mayor. As a result, the Mayor has not allocated resources to enforce the LEZ, but gave large numbers of exemptions to small businesses. In Germany, the ADAC (German General Automobile Club) and the trade bodies have been particularly negative towards LEZs. The ADAC has tried to take a number of LEZs to court, but had not been successful. The ADAC also produced a report, incorrect and based on poor science, stating that LEZs had no impact on air quality. The business associations have influenced a number of LEZs to have more exemptions or different areas than otherwise planned.

Needless to say, pressure from interest groups influences politicians. In some cases the politicians say that they have no choice but to implement due to rules from Europe, i.e. the legally binding EU air quality standards.

In northern Italy, where PM 10 pollution is particularly high, the north Italian regions made an agreement that they would also implement LEZs (affecting all vehicles), together with other measures for heating and financial incentives. This employed the 'safety in numbers' principle, minimising the competition potential of neighbouring regions being 'LEZ-free', and also increased political acceptance due to the fact that 'everyone's doing it'. In Italy the high number of exemptions and the often relatively short operation time periods (6 hours a day in the winter) of the LEZ also helped improving acceptability, but cannot be seen as best practice. The lack of information dissemination has on the other hand ceased negative reactions as people were penalised without knowing about the LEZ.

EU experience suggests that spreading information on LEZ is essential

- to enable vehicle operators to comply with the LEZ, which is harder, if they cannot find the information on the LEZ. The higher compliance the more impact the LEZ will have,
- to reduce motorists' and fleet operators' resistance.

There are a number of aspects to spreading information widely, such as clear signs, good national and local websites, news coverage, letters to those affected, adverts/placed articles in journals and newspapers, etc.
Consultation before implementation of a LEZ can help reduce stakeholder resistance and helps disseminate information on the planned LEZ. Working with key stakeholders at an early stage of the LEZ process can, in the long term, save time and increase acceptance. If the LEZs also affect private vehicles, then a more general public information campaign would also be recommended and a general mailing to the population within the LEZ could be considered.

2.4.2 Economic incentives, funding

Most EU countries have had financial incentives for retrofitting vehicles linked to the introduction of LEZs. The situation in the UK differs in that grants were in place before the LEZ announcement, and then withdrawn on the reasoning that where there was a 'stick', a 'carrot' was no longer needed.

The complimentary economic measures for replacing vehicles come in two types:

a) Scrappage grants for older vehicles on purchasing a new vehicle or
b) incentives (cheaper road tax, grants, cheap loans) for the very newest Euro V (now EuroVI) lorries and/or for retrofitting DPFs.

Scrappage schemes were in operation in a number of countries, usually for all cars over a certain age. The scrappage measures are usually more general schemes in Italy linked with the air quality management plan. Elsewhere (like in Germany) they were often implemented independent from the LEZ, but rather aimed at stimulating the economy during the recent economic 'crisis'.

In Germany, the only incentive aimed specifically at the LEZs is a 330€ tax incentive taken off the cost of retrofitting a private car with an approved DPF. Unfortunately, light and medium sized lorries were not covered, although especially small businesses would have better deserved financial support than private individuals, for whom public transport is a possible alternative to their car. Trucks larger than 12 t received a discount of the motorway toll, if equipped with a DPF and modern, cleaner trucks are charged less.

In Denmark, there was a national grant scheme for retrofitting approved DPFs to HDVs. The grant was up to 30% of the total cost, with a maximum of about 2000€ per grant and a total grant budget of 8 Mio Euro for 2004-9. There is also since 2010 a reduction on vehicle road tax (about 130€) for all diesel vehicles with a DPF fitted.

In the Netherlands there were significant grants to meet the whole fleet for DPF retrofit, which came out of the negotiations with the transport business that led to the LEZ covenant. Higher grants were given to retrofits that did not increase primary NO2. All cities are operating or planning better distribution centres to help improve logistics, as well as reduce the impact of the LEZ on logistics operations (LEZs affect only lorries). These will also reduce traffic and emissions.

If loans are for any reason not possible, hardship exemptions should avoid any business needing to close due to the LEZ, or serious hardship of individuals.

The advantage of complimentary economic measures is that they can increase acceptability. The disadvantage is their cost to the national/operating authority. Retrofit grants are the most common and LEZ-targeted form of complimentary measures.

Conclusions:
Complementary measures help with the acceptability of the LEZ. How much depends on their extent, but also on cultural aspects – the German population for example are particularly attracted to getting tax incentives. Grants towards fitting DPFs have been a particularly commonly used measure, and also well targeted.

Complementary measures can also help influence how the LEZ is complied with, for example encouraging DPF retrofits, which, especially if full filters are required, can have a more positive impact on PM10 emissions than complying with the next Euro standard. Differential grants for filters that do not increase primary NO2 have been also used to try to influence the choice of filter.

Most financial incentives have been organised on a national basis, and do not fully cover the cost of the compliance of the LEZ – as required by EU law. The 30% limit of grant funding set by the EU can also include costs of maintenance of DPFs.

The most significant disadvantage of complimentary measures is that they cost money, so increasing the costs of implementation.

2.4.3 Integration of LEZ in larger air quality and transport planning concepts

2.4.3.1 Example: Improve and promote alternative transport means

Non-financial incentives are less commonly used, but also very important parts of the wider air quality action plans. If LEZs affect private vehicles, local measures improving public transport would be a good way of providing complimentary measures. This will also have the potential to reduce traffic and congestion and therefore pollution in its own right. Improving logistics is another good measure.

In Berlin, for example, the LEZ was only one, admittedly the most important element of a larger set of measures being part of the city's air quality strategy. 6 out of 26 traffic-related measures aimed at avoiding and shifting motor traffic to other cleaner transport modes, such as:

- Promoting public transport by investing into an extension of the tram network, increased bus frequency through more and cleaner buses, bus acceleration with more separate bus lanes plus automatic priority at traffic signals – just to mention a few examples.

- Promotion of pedestrian and bicycle traffic through extension of cycle lanes, parking facilities, funding of electric bikes and further improvement of the intermodal connectivity with public transport

- Parking area management by extending the areas, in particular in central parts of Berlin with strong parking demands, where parking on the road is charged and the number of parking lots planned within new housing and development projects are limited

- Promotion of car sharing and urban logistic concepts for commercial traffic

As a result, road traffic volumes especially in central city areas of Berlin dropped by about 10% within a decade, resulting in a decrease of pollutant emissions from transport in the same magnitude as delivered by the LEZ.

2.4.3.2 Example: Public Procurement

As mentioned earlier, leading by example is important for greater acceptance of the LEZ, in that the public sector, including the public bus fleet, strongly invests in cleaner vehicles in order to fully meet or even exceed the LEZ requirements.

Taking the example of Berlin, the city has adopted a law enabling the city administration, including subordinated authorities and municipal companies to include environmental criteria in the procurement of goods and services. As a result, new purchased vehicles always need to meet the highest emission standard and/or should run on clean natural gas or electric power. Transport and construction service procurement needs to require the use of vehicles meeting the LEZ criteria or construction machinery with a DPF.

3. Differences between Europe and Mexico relevant for LEZ scheme design and implementation

It goes without saying that the experience with LEZ implementation in Europe cannot be directly extrapolated to the situation in the Mexican megalopolis.

The boundary conditions in Mexico are different from those in Europe, because

- the vehicle fleet composition in Mexico differs significantly in that passenger cars and light goods vehicles running on diesel are very rare. The vehicle stock is also much older with lots of used vehicles from the U.S. being sold in Mexico,

- the regulatory framework for type approval of vehicles is not harmonised, but rather refers to a mixture of U.S. and EU standards. That makes it difficult to use it as a basis for LEZ emission requirements.

- at least for the Megalopolis an elaborate mandatory in-use Vehicle Inspection Program (PVVO) and hologram scheme exists, which could be used as a basis for LEZ emission requirements. However, it is imperfectly enforced in practice and needs to be overhauled in order to reflect the recent progress in vehicle and emission control technology.

- cultural habits and socio economic conditions differ in Mexico. That may require a different strategic focus in the way a LEZ scheme is sold to the public and important stakeholders as well as in the means to ensure an efficient enforcement.

As a consequence, these factors are as much as possible taken into consideration in the following description of essential aspects and recommendations relevant for Federal State and municipal authorities in the Megalopolis region, if they consider developing and implementing LEZ schemes.

4. Recommended essentials for possible LEZ schemes in the Mexican Megalopolis region

4.1 LEZ area

When choosing the appropriate delimitation of the LEZ the following aspects should be taken into account:

(i) Cover a significant proportion of the roads, where the air quality is likely to be bad and where people live or frequently stay; should cover busy town centres, hubs of public transport, business and shopping centres, etc.

(ii) For motorists the zone is easier to recognize, if it is delimited by natural boundaries, like major arterial roads, railway lines, rivers, et cetera; this also minimises the requisite number of traffic signs marking the margin of the LEZ;

(iii) Define the size of the LEZ large enough so that the zone cannot easily be bypassed, as this shifts traffic in surrounding areas worsening the pollution situation there. In doing so, the desired effect on the vehicle fleet performance will be stronger as motorists can hardly avoid investing in cleaner vehicles or in retrofit.

As a rule of thumb the LEZ should cover an area where 30% or more of the population of the whole city live.

The size of the LEZ could be extended as part of a phased implementation of a LEZ scheme starting with a smaller area, for instance covering the historical town centre, during the first phase. Existing plans for *Ecozonas* in town centres, where traffic calming

measures and pedestrian zones are implemented, should be integrated in the planning of the LEZ area.

4.2 Type of vehicles

It is recommended to set emission-based requirements for access to a LEZ for all road vehicles with 4 wheels. Such a global approach has the following advantages in comparison with the option of a LEZ covering only heavy vehicles running on Diesel:

(i) Given the considerable share of older petrol cars without a catalytic converter at least outside of Mexico City, inclusion of passenger cars in a LEZ scheme would yield a significant emission reduction of gaseous pollutants, like benzene, other hydrocarbons and NOx. If implemented in all Megalopolis cities, it could make a tangible impact on photochemical pollution in the region, being is a severe problem in the Megalopolis. A LEZ limited to trucks and buses would yield no additional control of hydro-carbons and only little NOx emission reduction, because NOx control technology is limited to the newest Diesel vehicle generation, while retrofit of the vast in-use fleet of Diesel trucks and buses, is rather expensive, if technically feasible at all.

(ii) Including passenger cars could have a traffic-calming effect at least in the early phase of the LEZ as drivers of a non-compliant vehicle may find it more cost effective to switch to public transport than to change their vehicle or decide not to make the trip at all. Of course, the quality of public transport and its emission performance needs to be good in order to generate the expected benefit.

(iii) Covering only heavy vehicles, while old polluting passenger cars would still be allowed to enter the LEZ would be seen as unfair by the transport business operating non-compliant trucks. This could spark resistance against the LEZ and make its introduction more difficult.

Retrofit of closed loop catalytic converters should be allowed to qualify for compliance with the LEZ requirements. The same holds true for DPF retrofit applicable for Diesel vehicles.

The poor performance of public bus fleets in many cities in the Mexican Megalopolis could be improved by including them in the LEZ scheme. If so, emission requirements for buses and those for taxis should never be more lenient than for the rest of the vehicle fleet. Given the high mileage of these vehicles and their role model function, it is recommended to set even stricter standards for public buses and taxis. As an alternative, public buses and taxis could also be regulated separately by requiring these emission criteria within a system of concessions issued to bus and taxi companies willing to operate services in the respective LEZ city.

4.3 Emission requirements, phased introduction and exemptions

Setting appropriate emission-dependent minimum criteria for the access of vehicles into a LEZ is a crucial pillar of any LEZ scheme.

In general, a sound balance should be struck between **emission criteria which could be**

- too lenient, with little benefits for air quality, public health and urban living, because they would affect only a tiny part of the vehicle fleet

- too strict, with a strong impact on the air quality but also exerting a severe burden in particular for businesses relying on their (commercial) vehicles non-compliant with the emission criteria.

While the emission criteria are the core parameters determining the stringency of the LEZ, there are **other factors determining the ambition level**, like

- the availability of cheap options to retrofit non-compliant vehicles so that they can again access the LEZ,
- the length of the transition period between the official announcement of the conditions and their practical enforcement,
- the number of stages foreseen to fully enforce the scheme,
- whether LEZ restriction is enforced durably or only during certain time windows
- whether exemptions are granted and how strictly they are designed,
- the extent of funding provided to generate economic incentives and to soften the financial burden especially for the affected businesses,
- other complimentary measures, like attractive means of transport available to residents so that they would not depend on using their car.

4.3.1 LEZ emission requirements

It is recommended to take **the existing Hologram scheme** of the Mandatory Vehicle Inspection Program, PVVO, as a starting point for setting emission requirements to be met for vehicles in LEZ schemes in the Mexican Megalopolis.

The Hologram scheme already defines certain emission categories to be met for vehicles during the regular emission testing. It is seen as advantageous that the Hologram scheme already offers a well-known labelling scheme, which in principle allows a categorisation of the vehicles related to their emission performance.

Taking the in-use emission testing categories of the PVVO as a basis deviates from the conventional way of linking the emission criteria for LEZ schemes to the vehicle emission standards for type approval of new vehicles (see Section 2.2.1 for the EU approach). In the conventional approach, when introducing a LEZ in several stages or when tightening the scheme after a certain time so as to accommodate with the progress in vehicle technology, the access restriction criteria would gradually be changed from older to newer emissions standards.

For similar reasons, the emission threshold underpinning each Hologram class, say category 1, will need to be tightened with time, as the vehicle stock gets more modern and, hence, less polluting, so that the PVVO still serves its purpose of controlling real-world emissions of all in-use vehicles. The requisite update also concerns the prescribed

techniques for emission monitoring and other features of the PVVO relevant for the effectiveness of the program.

So, when grounding the emission requirements of a staged LEZ concept on the in-use emission limits of the Hologram scheme of the PVVO (e.g. on category 1 for LEZ stage I and 0 for stage II) **account needs to be taken of any change of the underlying emission concentration limits and other relevant attributes enshrined in the Hologram scheme.**

Consequently, as the emission limits of the current **Hologram** scheme hasn't been adapted to improvements in vehicle and emission monitoring technology for quite some time, **such a revision**[4] **needs to be done first, before LEZ requirements are defined on the basis of the Hologram categories. This should be done as a concerted action among the Federal States of the Megalopolis region.**

One exemplary feature that **needs to be overhauled** in order to suit the purpose of a LEZ – for example to keep out Diesel vehicles without a Diesel particle filter (DPF) and to promote DPF retrofitting – is **the opacity limit, Diesel vehicles** must not exceed during the emission testing. With technological progress, more vehicles with a DPF will enter the market. Moreover, it should be a prominent goal of the LEZ concepts to also promote filter retrofit in order to speedily reduce toxic diesel soot emissions of the Diesel vehicle fleet driving in Megalopolis cities. The **current set of opacity thresholds is too insensitive** to allow a distinction between vehicles with and without a filter or to detect malfunction of existing DPF. An opacity level of 0.15 m^{-1} is set in Switzerland as a benchmark to be fulfilled by machinery equipped with a functioning DPF. This seems also largely be applicable for light and heavy road vehicles[5] with Diesel engines. In order to monitor such a lower opacity level more sensitive instrumentation is required, i.e. second-generation opacimeter based on laser light scattering rather than the conventional opacimeters using only light distinction.

Table 1 presents stricter opacity limits suggested for a revised Hologram scheme for Diesel suitable also as emission requirements for a LEZ. It also includes recommended changes of many of the other emission thresholds applicable for petrol and gas driven vehicles, which have been taken from a note prepared by CAMe. It is therefore recommended to still scrutinize the proposed figures together with appropriate vehicle emission experts at CAMe, World Resources Institute Mexico, Centro Mario Molina or other suitable institutions in the light of the Mexican vehicle emission standards[6], the PVVO regulation, the specific characteristics of the Mexican vehicle stock and other relevant information.
As described in Section 2.2.1 above, it is good practice when setting LEZ emission criteria to allow retrofitting with DPF or a closed-loop catalytic converter.

[4] On necessary adaptions of the PVVO see paper by the Mario Molina Centre referred to in Annex I.
[5] See report from TNO on roadworthiness tests of DPF listed in in Annex I.
[6] See Annex I for the emission standards defined in Mexico.

Table 1: Proposal for updated emission limits for the Hologram scheme of the PVVO

	Petrol/Gas vehicles					Diesel
Emission category	HC (ppm)	CO (%vol)	NOx (ppm)	O2 (%vol)	lambda	Emission standard or Opacity (m^{-1})
00	70	0.1	100	0.3	1.03	Euro VI/5 EPA2010 0.15
0	80	0.4	250	0.4	1.03	0.5
1	100/200	0.8	1000/800	0.5	1.05	1.2
2a	100	1.0	1500/800	2	1.05	1.6
2b	350/200	2.5/1	2500/1000	2	1.05	2.0

The Hologram scheme should therefore reward investments into better emission control technologies by **allowing an upgrade to a better Hologram category for vehicles retrofitted with a catalytic converter or a DPF**. So, a vehicle once falling into a certain emission category, say 1, should be allowed to move up to a better category provided that it meets the stricter emission limits during the PVVO emission testing.

As an example, an older petrol car, being a retrofitted with a three-way catalytic converter would likely meet the emission limit of category 0 and could therefore be upgraded from its initial class 1 or 2 into or category 0. Similarly, a diesel truck or bus initially having Hologram "1" could gain even Hologram "00" when retrofitted with an effective wall-flow DPF, which normally filters about 99% of the (even ultra-fine) soot particles, so that opacity levels would drop below the suggested emission threshold of 0.15 m^{-1}.

Clearly, as the classification for diesel vehicles is solely based on the opacity level, allowing an upgrade of an older vehicle into a better category because of a DPF retrofit would not necessarily lead to a better NOx emission performance. On the contrary, a number of DPF systems might even increase the share NO2 in the exhaust gas. In order to avoid such kind of negative side-effects and to ensure that only DPF systems with a certain filter efficiency are allowed to be retrofitted, **DPF-certification should be mandatory** ensuring that DPF meet these essential features. The same is true for the technical properties of retrofit kits for catalytic converters.

Preferably, retrofit standards should be defined on a national level, so that it sets a nationwide standard, based on which **all retrofit devices built in in Mexico would need to meet the same technical features**. As a minimum, this could be regulated across the Megalopolis States.

Rather than inventing something new, it is **recommended to refer to already existing international certification standards for retrofitted emission control devices**,

- **for DPF** for example to the REC-Regulation[7], recently adopted under the United Nations Economic Commission for Europe (UN-ECE), which might become a world-wide regulatory for retrofit of Diesel after treatment systems, including DPF .While there are still few DPF system certified with reference to the REC – regulation, a far larger number of DPF have been tested by the internationally renowned Swiss VERT[8] association. The VERT certification scheme has become an internationally accepted industry standard, which was basically enshrined in the REC regulation. The California Air Resources Board (CARB) also has a certification scheme for DPF[9] in place, which could also be taken as a reference for a Mexican retrofit certification scheme.

- **for catalytic converters** it would be most appropriate to refer to CARB's retrofit scheme[10], because many in-use petrol vehicles in Mexico prone for retrofit are of U.S. origin

4.3.2 Operation time and phased introduction of LEZ schemes

As stated earlier in Section 2.2.3 introducing a LEZ scheme in several phases would be the preferred way forward as this allows the worst polluting vehicles to be removed in the first phase and the population to get used to the LEZ concept. This means starting with a weaker emissions standard which is then tightened after a period of time.

Following the good practice examples for LEZ operation times in Europe it is **strongly recommended to operate the LEZ continuously**, rather than only during pollution episodes, every second day or even only once a week as required by the "hoy no circula" scheme in Mexico City. While the latter promotes purchase of second cars, shifting car trips into periods with free access and therefore diluting the emission savings effect, a durable operation, preceded by a sufficiently long pre-warning phase, is easier to sell to the public and results in a stronger modernization of the vehicle fleet.

Table 2 presents a proposal for a phased way of introducing durable LEZ schemes in the Megalopolis.

Table 2: Proposed stepwise introduction of emission requirements for access to a LEZ in the Mexican Megalopolis

[7] UN-ECE Regulation No. 132: Uniform provisions concerning the approval of Retrofit Emission Control devices (REC) for heavy duty vehicles, agricultural and forestry tractors and non-road mobile machinery equipped with compression ignition engines. Addendum 131 to the "Agreement Concerning the Adoption of Uniform Technical Prescriptions for Wheeled Vehicles, Equipment and Parts which can be Fitted and/or be Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of these Prescriptions". Web access: https://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/updates/R132e.pdf

[8] See the VERT Association's (Verification of Emission Reduction Technologies) website with a list of VERT-certified Diesel particle filter systems: http://vert-certification.eu/

[9] for more information see http://www.arb.ca.gov/msprog/decsinstall/decsinstall.htm

[10] for more information see http://www.arb.ca.gov/msprog/aftermktcat/aftermktcat.htm

Engine type	Transition phase	Stage I (timing should coincide with improvement of public transport)	Stage II
Positive-ignition engine (i.e. passenger cars and light goods vehicles running on gasoline, CNG or LPG), except taxis/buses	Require strict enforcement of the existing vehicle inspection regulation during the transition phase, if not everywhere, then at least in the LEZ; this should include in particular the enforcement of the regular change of the catalytic converters with degraded efficiency	Hologram 1 as a minimum, (includes upgrade from Hologram 2 to 1 through retrofit with a closed loop catalytic converter so that the emission limits of category 1 are met)	Hologram 0 as a minimum (includes upgrade from Hologram 1 to 0 through retrofit or renewal with an new effective closed loop catalytic converter, so that the emission limits of category 0 are met)
Compression-ignition (Diesel), except local, public buses/taxis		Hologram 1 as a minimum (includes upgrade from category 2 to 1 by retrofit with a certified Diesel particle filter)	Hologram 0 as a minimum (includes upgrade from category 2/1 to 0 by retrofit with a certified Diesel particle filter)
Local Public Buses/taxis* with compression-ignition engine (Diesel)		Hologram 0 as a minimum (includes upgrade from category 1 by retrofit with a certified Diesel particle filter)	Hologram 00 as a minimum (includes upgrade from category 1 by retrofit with a certified Diesel particle filter)
Taxis/buses* with positive-ignition engine (gasoline, CNG or LPG)		Hologram 0 as a minimum, (includes upgrade from Hologram 1 to 0 through retrofit with a closed loop catalytic converter so that the emission limits of category 0 are met)	Hologram 00 as a minimum (includes upgrade from Hologram 1/0 to 00 through retrofit or renewal with an new effective closed loop catalytic converter, so that the emission limits of category 00 are met)

* As an alternative, public buses and taxis could also be regulated separately by requiring these emission criteria within a system of concessions issued to bus and taxi companies willing to operate services in the respective LEZ city

The ambition level of stage I and II in terms of the minimal Hologram category required for driving into the LEZ is recommended to differ between ordinary vehicles and taxis and local buses. The latter are treated in a stricter way because of the higher mileage. Moreover, taxis and local buses are part of the public transport system, which should be an attractive and less polluting alternative to private car use. That's why the minimum requirement proposed in Table starts with hologram 0 in stage I, followed by stage II stipulating hologram 00, which requires a highly efficient DPF on the latest EU/US emission standard, where a DPF is needed anyway.

For ordinary vehicles stage I requires hologram 1 as a minimum. If the upgrade option will be enshrined in the hologram scheme as recommended above, category 1 would also allow

access of vehicles, which initially belonged to a lower hologram category, but qualified for an upgrade, because they were retrofitted with an efficient catalytic converter or a DPF, meeting the emission limits of hologram 1.

The same logic applies to stage II, but with the minimum hologram category 0.

When selecting an **appropriate timing between the different steps**, the following aspects should be taken into account:

- **The proportion of vehicles affected by the LEZ** access restriction and the emerging pollution reduction: As the share of banned vehicles actually determines the stringency of the approach, it is important to have a robust estimation of the affected part of the vehicle stock. In that respect it should be distinguished between more expensive replacements of vehicles by new(er) ones or a retrofit and subsequent upgrade of non-compliant vehicles, which is in many cases a cost-effective, less burdensome solution. As a general rule, it can be said, that the more vehicles are affected by the respective access restriction criteria, the more adaptation time should be granted for vehicle owners. It is recommended to foresee a longer transition period in combination with stricter requirements instead of going for a rather lenient approach, which might not yield much of the promised air quality improvement and therefore could compromise the usefulness of the whole concept.

- Providing **funding for scrapping old vehicles and for retrofits** (see Section 4.5 for details) would ease the burden and therefore increase the environment benefits, because a more stringent approach could be acceptable for affected car owners, if they received some financial support. This is especially relevant for small businesses as they rely on their vehicle fleet much more than private car users and often lack the financial means to invest into a better vehicle or into retrofit.

- Allowing **exemptions limited to genuine cases of hardship** (see following Section 4.3.3 for details).

- The **availability of alternative and attractive means of transport** for private car users could allow being stricter without sparking too much resistance and rejection by the public. Better infrastructure for cycling and a more efficient public bus transport are examples.

Assuming implementation of the propose LEZ scheme plus the afore-mentioned supporting measures, it **is recommended allowing for about 2 years transition phase** between the formal adoption of the LEZ concept after a public consultation phase and the start of the access restriction in practice.

This should enable affected car owners and vehicle operators to provide for requisite investments into making their vehicles compliant with the LEZ requirements. The transition period can also be used to prepare for a smooth launch of the LEZ scheme and complimentary measures, such as the improvement of public transport and other transport means, to be put in practice on time before the access restriction comes into force.
A similar time period of about two years is considered appropriate between stage I and II.

It should be noted that the timing can be shortened or extended depending on the specific local boundary conditions and other relevant factors like those mentioned above. As an option, the transition period could be shortened considerably in combination with a subsequent Phase 0, which would be launched within a few months after the adoption of the scheme with an access restriction applying only to the dirtiest Hologram category 2b.

Phased introduction of a LEZ scheme does not need to be limited to gradually tighten emission criteria. A stepwise extension of the LEZ area could also be considered, for example by starting with a smaller LEZ covering a historical town centre (e.g. an *Ecozona*) and adding surrounding areas to the LEZ access restriction scheme later.

4.3.3 Exemptions

As already mentioned in the previous section, exemptions from the LEZ access restriction should be defined for certain vehicles and/or special circumstances in order to account for potential cases of hardship caused by the access restriction. This would enhance acceptance of the LEZ approach by business and private car owners.

General exemptions applicable to a whole category of vehicles are recommended for

(i) emergency vehicles (e.g., ambulance, fire trucks, police vehicles)
(ii) handicap vehicles
(iii) diplomatic and military transport

Granting exemptions to non-compliant emergency and handicap vehicles seems justified, because replacing these vehicles with new ones is usually extremely costly as they are often equipped with sophisticated and expensive equipment. As far as these vehicles are operated by the public sector, **investments into cleaner LEZ- compliant vehicles or in retrofit should be stipulated** as part of a wider strategic plan to improve the air quality in the LEZ city. This is important, given the model role the public sector ought to play in order to be able to credibly request similar efforts from the private sector and citizens to make their vehicle compatible with the LEZ criteria.

For the same reason it was recommended earlier **not to grant any exemptions to the public bus transport** as this is rightly considered as a public service even if it's operated by private bus companies (see Section 4.9 for ways to incentivize clean public buses) .

Key components of the permitted exemption for the LEZ should be outlined in the proposed **LEZ regulation**, while **details should be spelt out in an administrative instruction** to this regulation.

The list above intentionally excludes residents or companies living or residing in the zone. Granting them a general exemption would necessarily concern a significant share of the vehicle stock and therefore lessen the expected pollution reduction to a large extent. As noted in Section 2.2.1, it seems more appropriate and easier to sell to the public, if **exemptions are granted very thrifty, but in combination with a longer transition period instead**.

In addition, individual exemptions granted to a specific vehicle for a limited time period should be allowed upon application. As a **general principle exceptions should only be**

allowed for vehicles, which cannot be retrofitted with a relatively cheap catalytic converter (Otto-engine) or a DPF (diesel engine) and therefore not be upgraded to a better hologram category required to drive in the LEZ. As retrofit should not constitute an unacceptable financial burden, there is no reason to offer a way to avoid investing in lowering the vehicle's emissions.

So, for vehicles, which cannot be made compliant with the LEZ requirement, exemptions could be granted in the event of **a severe hardship**, because neither

(i) an alternative means of transport nor
(ii) the financial means for purchasing a LEZ-compliant vehicle are available.

As (i) mostly applies to commercial vehicles, conditions for **exemptions granted to companies**, in particular to small businesses with poor financial resources, should be **less strict compared** with exceptions for private car use, where public transport and cycling could be seen as an acceptable alternative, unless car users are nightshift workers or handicapped with mobility problems.

For companies with a larger fleet of commercial vehicles temporal exemptions could be offered for non-compliant vehicles, if a certain share of vehicles already complies with or even over-accomplishes the LEZ conditions.

Applications for exemptions should **only be approved**, if **compliance** with the said conditions can be **demonstrated by appropriate documents**, such as

- an attestation of a vehicle inspection centre confirming that the vehicle cannot be retrofitted,
- a disability certificate,
- documents showing a precarious financial situation of the company, e.g. a tax bill and
- a prove that buying a new vehicle would be extremely costly because the old one has special features, etc.

Requiring this paperwork looks like superfluous bureaucracy, but aims to ensure a fair awarding of exemptions. On the other hand, easing the application and release of exemptions too much would likely result in too many polluting vehicles exceptionally driving in the zone.

For the same reasons **exemptions should not be released for free, but rather at the charge** somehow linked to the value of the exemption, that is the saving due to the allowed suspension of the investment into cleaner vehicle until the exemption will expire. Issuing exemptions for free would discourage investments in clean vehicles and be considered as unfair by those who already did. **Validity of exemptions should be limited** (e.g. two years maximum) and fees related to duration and the size of the vehicle. In order to avoid corruption, it is paramount that the **release and approval of exemptions is limited exclusively to public authorities**.

The basic principles of the exemption scheme should be laid down in the regulatory LEZ framework underpinning the LEZ in a harmonized way for the whole Megalopolis region.
While limited flexibility could be allowed in local frameworks in order to accommodate to city-specific circumstances, different ways of awarding exemptions for the same situations

should be avoided, in order not to spark a competition among neighbouring LEZ cities for the most lenient approach.

4.4 Vehicle identification and enforcement

As noted earlier, **effective enforcement and sanctions are key** to avoid losing acceptance for the LEZ scheme by those who abide by the rules.

Manual enforcement by the police and/or traffic wardens is considered best for the circumstances in the Megalopolis, as automatic surveillance technology requires high financial resources, which are barely available.

The following considerations should be taken in to account when setting up an efficient enforcement mechanism:

- The enforcement should be sufficient to deter non-compliance and achieve fairness for those who comply
- Penalty points on the drivers licence gives strong incentive to comply, as the license could be withdrawn in the event of repeated violation of traffic rules, including the LEZ traffic ban. The advantage is that it gives a significant incentive particularly for professional drivers to ensure that the vehicle they are driving complies.
- Fines and penalties should be sufficient (like the fines imposed on speedy cars caught by speed meters in Mexico City) to give an incentive to comply, for example comparable to the cost of complying, particularly if penalty points are not used
- The less likely the vehicle is to be detected, the higher the penalty should be.
- The higher the fine, the easier it is to enforce for foreign vehicles.

Hence, effective penalties for violations of the LEZ restriction need to be defined as part of the regulatory framework underpinning the LEZ scheme.

While the existing vehicle inspection regulation already foresees regular control and enforcement of the Hologram scheme, in practice it seems to be enforced in a very lax way. This flaw should be rectified by **regular controls and strict enforcement by imposing fines for non-compliant vehicles without a hologram at least in the LEZ**, even better in whole city area. Needless to say, that sufficient educated personnel for police and traffic wardens needs to be provided to ensure sufficient surveillance of vehicles entering the LEZ.

In this context the division of competence for LEZ controls between police, traffic wardens or similar personnel employed by respective city should be clearly spelled out in an administrative agreement between the respective State Government and the responsible municipal administration. Sharing and ensuring transparency the revenues from the penalties could be an incentive for enhanced engagement by local authorities in effectively enforcing the LEZ.

4.5 Economic incentives

As described in Section 2.4.2 accompanying financial support for vehicle owners, in particular for small businesses, of non-compliant vehicles can considerably mitigate resistance and help accepting the LEZ.

So, is strongly recommended at least **provide funding for retrofits of DPF and catalysts,** as this is in most cases a very cost-effective means to lower vehicle emissions. As a rule of thumb **about 50% of the retrofit costs** should be covered by a funding scheme.

Depending on the financial resources available for funding, a **scrapping bonus** limited to the **oldest and most polluting part of the vehicle fleet** (e.g. older than 20 years) should be considered.

As with exemptions, all funding schemes granted by the Megalopolis States should be harmonized to the extent possible.

With regard to **freight traffic,** the LEZ will probably have a limited impact on the emission performance of trucks, as most of the long-distance HDV-traffic should go around the LEZ anyway. In order to **generate an incentive to renew the truck fleet in the region or to invest into DPF retrofit, it is recommended to incorporate in the existing motorway toll system an emission dependent charging element, which favours clean trucks, especially those equipped or retrofitted with a DPF or running on natural gas.** Revenues of the motorway toll system can be kept constant, if trucks with high emissions would pay more instead. The price differential between cleaner and polluting trucks should be set in a way that investment costs into cleaner vehicles or DPF retrofit will amortise fairly quickly. Clearly, as the toll system is probably a countrywide scheme, individual State Governments might lack the requisite jurisdiction to change the road pricing system. However, in a concerted action together with other states of the Megalopolis sufficient political weight could be gathered to transform the toll system into a more sustainable scheme.

4.6 Impact assessment

As LEZ schemes solely aim at curbing road vehicle emissions, access restrictions for vehicles appear to be appropriate only if road traffic is the predominant source of the air quality problem in the urban area concerned. Unless it is fairly obvious that road traffic is the main polluter a study **analysing the sources** of the bad air quality should be conducted beforehand, preferably providing quantitative estimates of the share of different sectors on the problem. Ideally, such as study should answer the question to what extent a LEZ scheme with an access restriction based on different options for vehicle emission requirements could mitigate the situation.

In order to get sufficient support by the public and important stakeholders it is recommended to undertake a thorough **ex-ante and ex-post impact assessment study** of the LEZ.

Ideally such an analysis could consist of

- **the Fleet composition** taken from the vehicle registration database in the LEZ city or monitoring vehicles travelling in the LEZ **in terms of emission category ("hologram")** and differentiated for each vehicle category. This is important not only to show the impact of a LEZ on the vehicle fleet, but also to create a sound basis for choosing the appropriate emission category for the LEZ. After the LEZ is in force, the real data could be compared with a 'business as usual' scenario or the national fleet. The difference shows the impact of the LEZ on the vehicle fleet, which in turn leads to air quality improvements.

- an assessment of the **Traffic volumes** in and around the LEZ, specifically for major roads with air quality problems. The aim is to identify changes in the vehicle fleet and/or traffic flows due to the LEZ. Such data is also an indispensable input for emission and air quality modelling. Traffic volumes could be automatically measured with traffic sensors, which count the vehicles and distinguish between different vehicle categories. If automatic monitoring of the vehicle fleet composition on the road will not be feasible, conduct temporary 24h recordings with video cameras of the driving vehicles on a representative workday and subsequently retrieve manually the Hologram class and the emission category of the vehicles. This should be done at selected representative locations, preferably including the roadside spots with air quality monitoring.

- **Emission calculation for major road sections.** This requires an emission factor database for the Mexican vehicle fleet. If available, use the emission factors as much as possible representative for an urban driving mode. In the absence of emission factors for the Mexican fleet, U.S. factors could be used as a proxy, given that most of the used vehicles originate from the U.S. market.

- **Air quality monitoring,** allowing the 'actual impact' to be measured at traffic sites having high flows for the vehicles affected by the LEZ. There should be both background and traffic monitoring sites, incl. reference station(s) outside the LEZ. The impact of weather and non-LEZ measures needs to be accounted for – often by comparing monitoring inside and outside the LEZ. However, areas outside the LEZ are also affected by the LEZ, as cleaner vehicles travel into the LEZ. Focus should be on gaseous pollutants (NOx, benzene) related to traffic and likely to be altered by the LEZ, which are easy to measure with diffusion tubes or micro sensors, if standard automatic monitoring sites are still lacking. Black carbon (EC, OC) measurements with appropriate micro sensors should be added, if possible, because of the toxicity for human health and the strong relationship to the desired emission control by the LEZ of lorries, trucks and buses running on diesel. PM10 and PM2.5 should be measured, if possible. If routine air quality monitoring sites are lacking, appropriate sites for passive samplers/micros-sensors should be selected at road side spots with heavy traffic, were changes of the vehicle fleet and/or traffic volumes are expected. A reference site representative for urban background should be included. Co-located sampling should be done at a continuous automatic station, if possible, to ensure data quality and equivalence with the automatic monitoring station. Measurements should be conducted during a sufficiently large period (several years) covering the status quo before the LEZ and after its introduction. In any case, given the scarce density and poor quality of the existing monitoring infrastructure, more resources should be

allocated to improve the air quality data base for routine information of the public and for impact assessment of control measures.

- **Optional air quality street canyon modelling.** While model results are weather-neutral and could be used for ex ante scenario calculations, models need emission factors, vehicle fleet composition data or estimations as well as traffic volumes and the geometry of the street canyons. The air quality modelling results should be validated against monitoring data to reduce some of the uncertainties. Emission factors are estimates based on vehicle measurements and are a key uncertainty. An emission factor database for the Mexican vehicle fleet is required in order to achieve realistic results. As air quality modelling requires technical and scientific knowledge as well as sound input data, which is hardly available on the short-term, the application of such tools goes beyond the competence available to State governments, let alone to municipal authorities in charge of air quality management. So, collaboration with research institutions or universities is recommended, preferably supported and coordinated by the national government, in order set up the necessary data base and to develop the requisite expertise for air quality modelling at least in the medium-term.

4.7 Public information and stakeholder involvement

As a LEZ access restriction does affect virtually every business and resident within the zone and adjacent areas, it is important before planning the details of a LEZ scheme and prior to its implementation to

- **identify** the most important **stakeholders and target groups** (for example residents in the LEZ and its vicinity, local businesses, freight distributors, taxi driver associations, etc.) and to involve them in the development of the LEZ scheme,

- **identify appropriate media** to be used for the dissemination of information to the above-mentioned target groups. It is important to ensure as wide coverage as possible, taking into account the specific habit of the public in the Megalopolis cities. The types of media to be covered should include the press, radio/TV, Internet, leaflets and clearly visible information at the future LEZ margins as well as international best practices.

- **identify the appropriate content** of released information on the LEZ. While it is important to inform people about the elements of the planned LEZ scheme (e.g. area covered and its boundaries, access criteria, exemptions, sanctions), it is also pivotal to include information on the likely benefits for public health and the living conditions in the respective LEZ city.

- to pursue a **participatory approach** by inviting interested citizens for ideas and feedback on the proposed LEZ concept. One way to ensure direct contact with the public is by setting up an information desk by the competent authority, where interested people could find more information and could leave their suggestions or comments on the LEZ by e.g. filling in questionnaires. Other options include phone lines, email or postal addresses, and interactive internet blogs, considering that different target groups preferred different types of communication.

Stakeholder involvement already during the drafting and preparatory phase of the LEZ development is particularly advisable with regard to transport businesses, firms and companies located in the LEZ area, because they might have the largest need for investments into cleaner vehicles complying with the LEZ requirements. It is recommended **to organize workshops with business associations** where the draft LEZ concepts would be presented and information on the specific needs of companies affected by the LEZ could be taken up.

During the operation of the LEZ it is equally important to provide information in order to ensure the continuous effectiveness of the LEZ. This is especially relevant for drivers coming from neighbouring cities or Federal States. While all the information mentioned above should still easily be accessible and constantly updated, it should be supplemented with statistical data allowing the public to get to know the advantages and positive effects of the implemented LEZ.

4.8 Regulatory framework and collaboration between different administrations

It goes without saying that a LEZ scheme needs to be underpinned by a regulatory framework, which consists of a LEZ regulation determining the key rules, plus one or more administrative instructions describing the details in order to make sure, that the responsible authorities implement and enforce these rules in an efficient and consistent way. It might also be necessary to lay down relevant cross-departmental responsibilities in an administrative agreement between the respective State Government and the responsible municipal administration.

The regulatory framework should deal in particular with

- the details of the LEZ emission requirements,
- key components of the permitted exemptions for the LEZ,
- effective penalties for violations of the LEZ restriction and the sharing of the revenues,
- the division of competence for LEZ controls between police, traffic wardens or similar personnel employed by the respective city,
- (co-) financing of the necessary resources and economic incentives, grants, funding schemes, etc.

It is strongly recommended to **harmonize the regulatory framework** as much as possible **among the Federal States** and cities considering implementing a LEZ scheme in the Megalopolis. While limited flexibility could be allowed in local frameworks in order to accommodate to city-specific circumstances, different ways of regulating the same issues in different LEZ should be avoided, in order not to spark a competition among neighbouring LEZ cities for the most lenient approach.

This is especially **important for emission requirements, exemptions and funding schemes** granted by the Megalopolis States with a LEZ in force.

Careful planning and successful implementation of a LEZ scheme is a complex interdisciplinary project requiring sufficient resources of experienced personnel familiar

with the manifold technical issues and administrative aspects linked to the LEZ planning and implementation process.

It is strongly recommended to **define one department**, either the one in charge of environment or the Secretaría Ejecutiva de la Gubernatura, **to take the lead** and to co-ordinate the requisite technical steps during the preparatory and implementing phase of the LEZ.

As the above description of tasks and steps towards a successful development of a LEZ scheme suggests, the emerging work load mostly exceeds the available staff capacities and can hardly be managed simply as a side job of existing personnel.

The risk of failure should be minimised by **allocating extra personnel resources** to the management of the LEZ project, for example by creating at least one additional post in the leading department exclusively for the purpose of steering the planning and implementation of the LEZ over the next couple of years.

It goes without saying that the LEZ planning and implementation process is a highly interdepartmental business **requiring a close and mutually supportive collaboration between different parts of the administration** with sometimes different preferences and objectives. In order to ensure a constructive working spirit between different departments both on Federal State level and the respective city administration, it is recommended to set up two working platforms:

- A **LEZ steering group on political level** with the Secretaries (or vice-secretaries) of relevant State Ministries and of relevant City Councillors dealing with LEZ-related topics, i.e. environment, transport, judicial affairs, police, economy and finance. This group, preferable chaired by the Secretaría Ejecutiva de la Gubernatura, should discuss fundamental issues of political relevance, agree on ultimate goals, set up the overall time schedule and decide on politically contentious issues. Ultimately, the whole State Government, in person of the State Governor, should bear the political responsibility of the whole LEZ planning and implementation process, but it's important that the municipal government supports it too.

- An **internal LEZ project group on technical level** with representatives of different administrations needed to effectively plan and implement the LEZ. This group will work on planning and implementation details. If necessary it will bring critical issues up to the steering group to be sorted out on the political level.

4.9 Complementary measures

As noted previously, the **LEZ concept should be** considered and presented to the public as an important measure to help solving the obvious problem of this serious air pollution from road traffic, but which is **embedded into a larger urban development strategy to achieve the objective of improving the environmental situation and the living conditions in the city planning a LEZ scheme.** In that sense **the LEZ is perfectly compatible and complementary with additional traffic calming concepts, like the *Ecozona* in Cuernavaca**, which inter alia aim to reduce motor traffic in the city centre, while the LEZ will ensure that the remaining, unavoidable road traffic will be managed in a less polluting way.

At the same time, the LEZ sets the criteria for a cleaner public bus transport, which might need to be expanded and be operated in a more efficient and user-friendly way.

As has been noted above public bus transport plays an important role as an alternative transport option for car drivers. Needless to say, that the public bus fleet plays a model role in terms of environment performance, which must not be treated more lax than other vehicles in the LEZ. So, there should be **no exemptions for taxis and buses** from the access restriction to the LEZ, because anything else could undermine the acceptance of the LEZ by the public and businesses.

As noted before, instead of setting stricter standards for public buses as part of the LEZ scheme, **ambitious emission standards to be met by the public bus fleet could also be established in the conditions of a new system of concessions** granted to private bus companies willing to provide bus transportation services within a new, more user-friendly bus network in the respective municipality. In that context, the **uptake of cleaner buses could be promoted by providing extra funding to companies running buses** using natural gas as a clean fuel and to support investments in the necessary gas station infrastructure.

Green public procurement is another important measure complementary to the LEZ, especially regarding municipal vehicle fleets. **Establishing clean vehicle purchasing standards for all municipal departments and contractors** can make a significant contribution to the urban vehicle emission reduction and at the same time promote cleaner vehicles to the private sector.

Annex I: Additional reading on LEZ

CLARS web platform with a wealth of information on existing LEZ schemes all over Europe. Web access: http://urbanaccessregulations.eu/

On LEZ scheme design and implementation

AEA Technology Environment (2003): The London Low Emission Zone Feasibility Study: A Summary of the Phase 2 Report to the London Low Emission Zone Steering Group (July 2003). Web access: http://content.tfl.gov.uk/phase-2-feasibility-summary.pdf

DEFRA (2009): Practice Guidance to Local Authorities on Low Emissions Zones (Practice Guidance 2), UK Department for Environment, Food and Rural Affairs. Web access: https://www.gov.uk/government/publications/local-air-quality-management-practice-guidance-2

ECORYS (2014): Feasibility Study: European City Pass for Low Emission Zones: Final Report, DG Environment. Web access: http://urbanaccessregulations.eu/clars-members/images/stories/EU_documents/LEZ_Final_Report.pdf

ECORYS (2014): Feasibility Study: European City Pass for Low Emission Zones: Annex A: Standards and Guidance Document. Web access: http://urbanaccessregulations.eu/clars-members/images/stories/pdf_files/LEZ_Final_Report_Standards_and_Guidance_submitted.pdf

Website with information on urban access restriction schemes, including low emission zones. Web access: http://urbanaccessregulations.eu/

On LEZ impact assessment on freight transport companies in Berlin, London Gothenburg LEZ

Browne, Michael, Allen, Julian and Anderson, Stephen (2005): Low emission zones: the likely effects on the freight transport sector. International Journal of Logistics Research and Applications, Vol. 8 No 4. pp. 269-281.

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On vehicle emissions

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Annex II: Abbreviations

ADAC	Allgemeiner Deutscher Automobil-Club (automobile club in Germany)
ATE	Association Transports et Environnement (automobile club in Switzerland)
CAMe	Comisión Ambiental de la Megalópolis (Environmental Commission for the Mexican Megalópolis)
CARB	California Air Resources Board
CNG	Compressed natural gas
CO_2	Carbon Dioxide
DPF	Diesel particulate filter
EC	Elemental Carbon
EU	European Union
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
HC	Hydrocarbon
HDV	Heavy duty vehicle
LEZ	Low emission zone
LPG	Liquid petroleum gas
NO_2	Nitrogen dioxide
NO_x	Sum of nitrogen monoxide and nitrogen dioxide
OC	Organic Carbon
PM10/PM2.5	Particulate matter aerodynamic diameter larger than 10/2.5 µm
PVVO	Mandatory Vehicle Inspection Program (Metropolitan Area of the Valley of Mexico)
REC	Retrofit Emission Control
UK	United Kingdom
UN-ECE	United Nations Economic Commission for Europe
US	United States (of America)
VERT	Verification of Emission Reduction Technologies