POLICY PAPER: Low-Emission Zones (LEZs) and Prerequisites for Sustainable Cities and Clean Air in Egypt

Ahmed El-Dorghamy, Maha Attia, January 2021

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EXECUTIVE SUMMARY

This policy paper aims to introduce Low-Emission Zones (LEZs) concepts in Egypt in a manner accessible to the general public and non-experts and experts alike. It aims to discuss the position of the country in terms of readiness to implement LEZs policies and recommend how to meet such ambitions in a manner suitable for the current circumstances.

Low Emission Zones are areas where access of polluting vehicles is restricted through various means. A concept initiated since 1996 in Sweden, initially targeting *diesel*-fueled Heavy-Duty Vehicles (HDVs) as a priority, but later expanded in scope to cover more types, and coupled with other measures to limit the uncontrolled use of private cars as well. Vehicle restrictions therefore imply that parallel measures are needed to ensure that the zone is friendly for the use of other mobility alternatives (i.e. LEZs must be part of a larger strategy that also addresses pedestrianization, cycling friendliness, last-mile commuting experiences, public transport, public space, etc).

Reducing dependance on private cars is further encouraged by ensuring that cities are *safe, comfortable,* and *enjoyable*. Such changes will gradually have further implications on the conservation of heritage, greenery, public space, and other elements of sustainable streets, cities, and urban communities. LEZs and its prerequisites and parallel measures are therefore all enablers for Egypt's Sustainable Development Strategy, *Egypt Vision 2030*, and the global Sustainable Development Goals (SDGs), specifically, SDG-11: *Make cities and human settlements inclusive, safe, resilient, and sustainable.*

Through extensive stakeholder consultations, reference to international experience, and analysis of the situation in Egypt, several recommendations have been developed to lay out the key steps and measures to pursue LEZs schemes in Egypt. Such recommendations were specifically developed with sensitivity to the local context and priorities in addressing air pollution risks in Egypt.

KEY RECOMMENDATIONS FOR EGYPT TO MEET THE 2030 SUSTAINABILITY TARGETS:

- **Set and enforce Low-Sulphur (Euro-5) Diesel fuel standards (or comparable low-Sulphur specifications) in Greater Cairo Region** (City-first approach) followed by nation-wide enforcement. This is in line with the current expansion in refining capacity and domestic production of Euro-5 diesel fuel (most recently with the production at the Egyptian Refining Company facility within the existing Mostorod Petroleum Complex [MPC]), as well as with the ongoing reduction on import-dependance as natural gas gradually penetrates the sector.
- **Implement schemes for cleaner Heavy-Duty Vehicle (HDV) fleets**, including replacement and scrapping schemes and retrofitting where feasible (i.e. at least to *immediately* ensure that all buses and trucks have emission control devices*/filters*, while upgrading the vehicle emission monitoring capabilities, in parallel to ongoing introduction of alternative technologies).
- **Establish a unit for *Sustainable Urban Mobility*** in the Land Transport Regulatory Agency (as per its mandates) in coordination with the Ministry of Environment, to enable and build capacity for mainstreaming low-emission zone planning and advancing coordinated *Urban Vehicle Access Regulations* (UVARS) in coordination with the Ministry of Environment and re-assess the capacity and the mandates of relevant committees addressing cleaner fuels and vehicles together with the Ministry of Interior and other relevant authorities.
- **Set and enforce updated vehicle Emission Standards and register emission classes** for Heavy Duty Vehicles (HDVs) as a priority, followed by Light Duty Vehicles (LDVs) and other classes.

- **Revisit EIA regulations/guidance for road projects** to have more comprehensive requirements for road construction projects, with focus on residential areas (currently road construction projects of up to 5km are only required to meet the lowest EIA requirements category even if in a heavily populated urban area).
- **Develop a roadmap and action plan for the LEZs scheme development for Greater Cairo,** including phased approaches in terms of regulations and geographic scopes, primarily led by the Ministry of Environment and the Land Transport Regulatory Authority mandated to consolidate mobility planning and UVAR schemes in Egypt.
- **Implement social safety-net measures to mitigate adverse social impact** on affected vulnerable groups, including redirecting revenues from LEZs measures toward such mitigation/protection measures.
- **Embrace emerging solutions for advanced air quality monitoring and management** to support LEZs planning and impact evaluation, such as emerging analysis techniques offered by advancements in using satellite data, artificial intelligence, and improvements in integration with traffic data for improved accuracy, and higher relevance and efficiency, and opportunities for improved coverage and cost reductions.
- **Nation-wide Low-Sulphur (Euro-5) diesel fuel provision,** and nation-wide deployment of LEZs schemes in other priority cities.
- **Include the LEZs in both the sustainable transport development strategy and the air quality vision for Egypt 2030** to be in line with the major development projects and to benefit from the ongoing public transport and road enforcements.
- ***Social Marketing* and communications planning:** An advisable cross-cutting theme across all activities and interventions is the need for adequate social marketing planning (to guide how the measures will be framed and communicated to the public, how acceptability and engagement shall be ensured, etc), which according to international experiences has been key to success.

The recommendations enlisted above are articulated to highlight issues that are specific to the circumstances in Egypt. There is abundantly available guidance on sustainable cities already available in existing literature by leading institutions, yet limited availability of content tailored to local priorities and contexts. In this respect, this policy paper is provided to *complement* the global state-of-art knowledge about sustainable cities in order to facilitate LEZs adoption in Egypt, and in some cases proposing means to *leapfrog* stages of development where possible.

1. Why Low Emission Zones (LEZs) in Egypt now?

Low Emission Zones (LEZs) are schemes under which restrictions on polluting vehicles are imposed within a certain demarcated zone, such as an entire city, a specific central business district or a historical area.

Air pollution in Egypt has for long been an alarming and a pressing challenge, but the enabling environment to move towards cleaner fuels and introduce alternative green technologies might not have been sufficient yet for such necessary clean-air transition. However, with recent promising developments in Egypt today, it is possible to re-assess such readiness.

Highlights of previous studies and policy recommendations noted the challenges of the high sulfur in diesel fuel (2,600 ppm according to CEDARE's studies) and high environmental degradation costs (can reach up to 1.4% of GDP[1]), and also highlighted the major challenge of absence of emission control devices in heavy duty vehicles (details discussed throughout this report).

However, with recent developments, today, this report discusses how Egypt is in a better position than ever to move from planning to action due to key enabling developments that are unfolding:

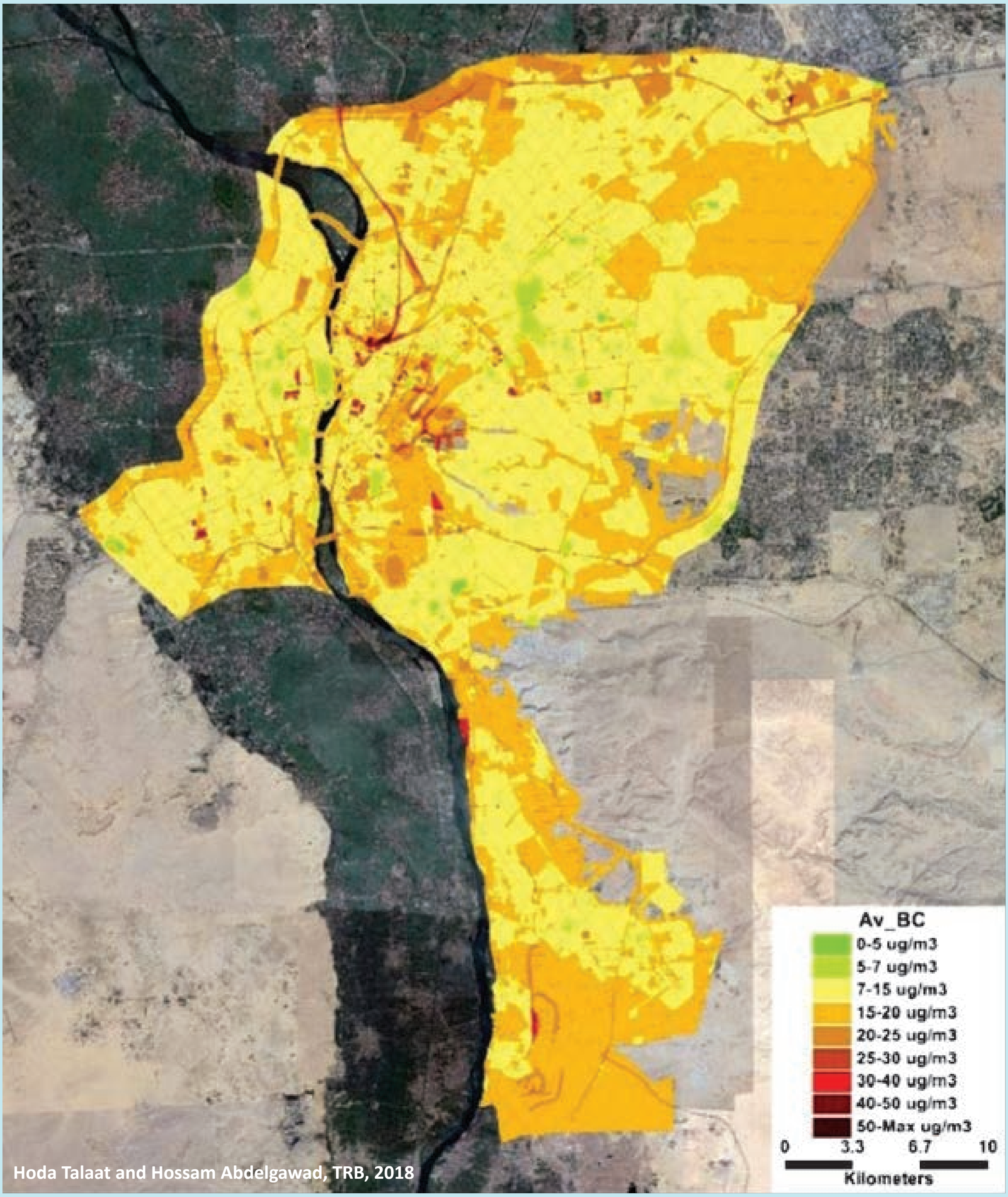
- The national agenda aims to shift from diesel fuel towards natural gas and electrification in the transport sector, driven by a strong and clear political will. This is further enabled by the recent developments in the power sector expansions providing cleaner electricity, as well as natural gas discoveries in the Mediterranean, which can gradually replace diesel fuel.
- Recent surge in the availability of *cleaner* diesel fuel (Euro-5) as new oil-refining capacity is introduced in 2019 (Egyptian Refining Company, ERC, among others in the pipeline).
- Egypt's initiation of the Intelligent Transport Systems (ITS) infrastructure nationwide and towards digitization of associated management systems and services, and mainstreaming of improved vehicle identification (RFID tags), all facilitating the enabling ITS infrastructure and accompanying measures necessary for mobility management and low-emission-zone implementation, monitoring and control.
- Expansion of the toll-stations network for improved management of on-road transport, which enables the options for polluter-pays interventions (and incentives for cleaner vehicles) along with the national road network development program.
- Egypt's initiation of manufacturing and roll-out of electric buses, electric cars and charging infrastructure, as well as development of a national strategy for electric vehicles.

Accordingly, today, more than ever before, it is possible to practically discuss a 'leapfrog' transition towards transformational cleaner air policies, including the powerful action of developing LEZ schemes. Such an opportunity would furthermore position Egypt as a leading nation in Africa and the Middle East, offering further inspiration and support to neighboring countries facing similar challenges.

This report argues that accordingly, many elements are already in place, and this policy paper aims to discuss 'connecting the dots' and calling for the endorsement of a powerful and much-needed comprehensive scheme. The report presents the global state-of-art knowledge about LEZs, lessons learnt from case studies, analysis of the situation in Egypt, and recommendations for the way forward, with the aim to address the challenges faced in Egypt's growing cities and rising rates of motorization.

Air Pollution in Egypt: Moving from Science to Policy

The following image shows a heatmap indicating high pollution levels (Black Carbon) in Greater Cairo, including 'hotspots' such as Ramsis Square[2]. Such insight is only valuable if it is later linked to policy and interventions. Today, more than ever before, Egypt can link science to policy, move from policy to practice, and implement measures to address this air pollution challenge to meet targets of the 2030 Agenda for sustainable development, as well as the commitment to a post-COVID-19 green recovery. Black Carbon is not only a local air pollutant impacting public health, it is also a 'Short-Lived Climate Pollutant' (SLCP) contributing to global warming.



Hoda Talaat and Hossam Abdelgawad, TRB, 2018

2. GLOBAL TRENDS IN LOW EMISSION ZONES (LEZs)

2.1 Global overview and LEZs definition

With rising global awareness about health and environmental effects of air pollution, especially in cities, more countries every day are taking evermore serious measures to mitigate emissions. Priority is given to reducing the observed high levels of nitrogen oxides (NOx), Particulate Matter (PM)[a], and greenhouse gases (GHGs) in urban areas through mitigating the effect of road traffic on emissions[3].

Road traffic contributes to around 39% of transport NO_x, 13% of PM, and 25% of GHG emissions[4]. Among the different successful policies applied to reduce transport emissions is the Low-emission zones (LEZs) policy. Initially, LEZs mainly focused on reducing PM from exhaust emissions, while the reduction of NO_x and GHG came as a secondary objective. However, NOx and GHGs have recently been tackled as a priority objective in LEZs in many cities[3]. Such emissions are produced mostly from diesel vehicles more than from conventional gasoline vehicles. Accordingly, the policy typically focuses on diesel vehicles as the initial priority[5].

Low-emission zones or Environmental zones can be defined as follows:

> Low Emission Zones (LEZs) are areas in which the most polluting vehicles are either not allowed to enter a specific (typically urban) area or are subjected to large fines if they do.

This policy started in 1996 in Stockholm, Göteborg, and Malmo in Sweden as a transportation-planning tool and a strategy that aims to reduce traffic emissions, targeting the most polluted urban areas[6].

European LEZs

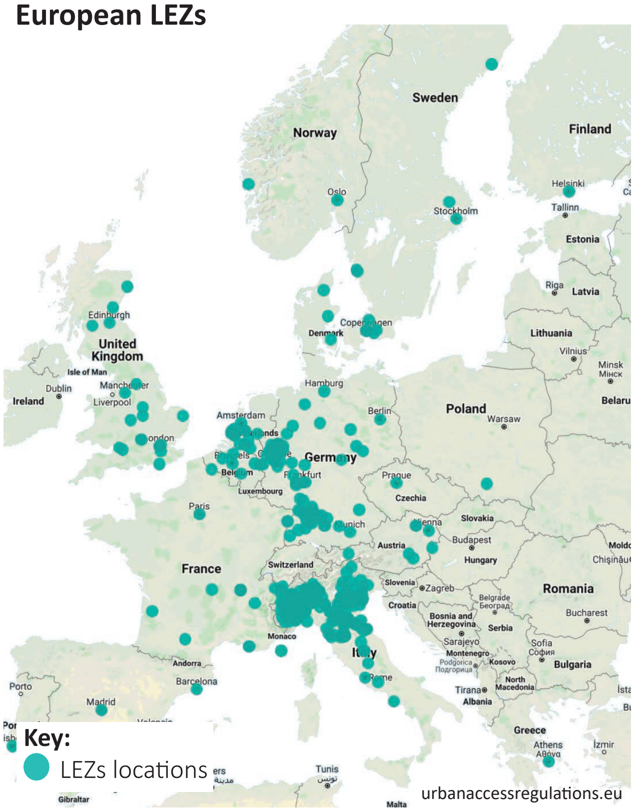


Figure 1: Different locations of LEZs at EU cities, 2020 [7].

Since 2002, the policy has been transferred to different countries and applied within different agendas and scopes of restrictions. As of 2020, there are more than 260 LEZs around Europe[3] (see Figure 1).

It is important to note that access regulations and pollution reduction policies are very wide in scopes, and diverse in terms of rules and labels. Some cities have the same LEZs regulation incorporated within a different policy name (e.g. Environmental zones, limited traffic zones, etc.). The policy marketing depends on the socio-economic nature of each city, and the approach to ensure the acceptability of its application.

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[a] Particulate matter (PM) refers to fine particles of PM_{10} (particulate matter less than 10 micrometers in diameter) and $PM_{2.5}$ (particulate matter less than 5 micrometers in diameter). The effect of LEZs in most cities is measured through the reduction of PM_{10} in the air.

Lessons from Rome: Protecting history and heritage

Rome, a city with immense historical value, is a good example of a global city implementing measures to reduce air pollution with improved vehicle access regulations. Rome started with a so-called Limited Traffic Zone (ZTL) since 1989. While this ZTL can produce similar environmental benefits to a LEZ, it was not emphasizing the environmental aspect from the beginning. It was rather mainly advertised as a measure for reducing the amount of traffic within the valued historical area. Rome was very successful in banning almost all private vehicles entry into the historic area, except for public transport, taxis, and private cars that belonged to residents who live and work within the zone. This way, the historic area was protected from the environmental and traffic pressures of tourism. Currently, Rome has seven zones with different scopes of regulations and restrictions (See example Figure 2). Only three of them are identified and advertised for as LEZs, but they collectively constitute a substantial set of interventions to reduce air pollution along with addressing traffic congestion[7, 8].

Figure 2: Limited traffic Zone, example of street signage in Rome. The restrictions in this zone is for all motorized vehicles except bikes, private cars, and motorcycles[9].

Consequently, throughout the many years of LEZs transfer to different cities, the policy was significantly affected by the urban contexts, and the social and the political status of the adopting city or country. The policy is either applied as a *national* scheme (e.g. Germany and Italy) that is yet context-flexible; or a *local* scheme that follows the overall national targets (e.g. Netherlands and the UK)[5]. The LEZs witnessed different lesson-drawing and policy diffusion patterns, which guided its continuous replication, and its context-based success.

2.2 Different scopes of LEZs

LEZs control the entry of specific vehicles from specific locations. Violating vehicles either pay a fine or are totally banned from entering the zone. The policy scope of influence is directly affected by the geographical and the regulatory decisions. Based on the different studies done

The Netherlands: National plan, local tailoring

In the Netherlands, LEZs are supported by the national government as a method that helps in achieving the required national air quality levels. So far, there are **15 LEZs** in different Dutch cities (see Figure 3), that have a significant impact on the local scale as well as on the national scale. For example, the national number of polluting vehicles in the Netherlands have decreased by 18% in 2017, compared to 2015. This decrease is attributed to the effect of the different LEZs [11].

Figure 3: LEZs locations in the Netherlands, 2020[5].

Until recently there were no unified regulations for LEZs around The Netherlands. Starting from 2020, the Dutch government decided to set minimum standards for heavy-duty vehicles (HDVs) and associated bans that should be followed in all LEZs. However, each city still has the freedom to choose whether to apply a LEZ or not and is encouraged to adjust the light-duty vehicles (LDV) regulations according to its context[7].

on LEZs, it is observed that the larger the geographic scope is, the lower the regulatory restrictions. Furthermore, all the policy decisions are adjustable and differ from one LEZ to another even within the same city.

Geographical and regulatory boundaries are set gradually and slowly to guarantee less social and political constraints, and to progressively promote more strict future steps. For example, in pioneering cities like London, LEZ stared in 2008 with the scope of the entire city, banning diesel HDVs of Euro IV and lower, in addition to diesel large vans and minibuses of Euro III and lower. In 2019 an *Ultra LEZ* has been introduced only around the city center boundaries, adding to the ban private cars, motorcycles, and minivans, etc. (smaller area, more strict rules)[10]. The city is planning that by 2021, requirement for the LEZ will be stricter and boundaries of the ULEZ will be larger[7] (See Figure 4).

bvrla.co.uk, based on Transport for London reports (adapted by authors).

Figure 4: London LEZ development and future strategies, 2020 [7]

Through this technique of steadily increasing scopes, future strategies can realistically pursue the application of the even more ambitious concept of *Zero-emission Zones* (ZEZs)[12].

2.2.1 Regulatory scopes

Regulatory scopes include technical aspects like, operating hours, vehicle type (e.g. HDV, LDV, etc.), engine type (e.g. Diesel, Petrol, etc.), emission class, pollutants, and year of vehicle manufacturing (See Figure 2). Ideal LEZs operate every day, '24/7' (exceptions are found in some cities and are being reduced). In the initial policy phases, LEZs affect buses, coaches, and heavy-duty vehicles (easily controllable through private sector licensing). Stricter LEZs affect vans, minibuses, and camper vans while extreme cases can further target private cars and motorcycles, although caution is warranted to avoid triggering political instability[7].

As diesel fuel combustion is a greater concern in terms of PM and NOx emissions, the LEZs policies largely focus on diesel-powered vehicles. Petrol vehicles are also included, but with less limitations as they are less polluting. Restrictions are based on the European emission standards (Euro-class) of each vehicle. Euro classes define the categories of vehicles as per the acceptable limits for vehicle exhaust emissions, for new vehicles sold or brought into the EU[12]. It is accordingly also associated with the age of the car, which indicates the level of pollution (See Table 1).

Table 1: Example of the European emission standards limits, indicating HDVs emission limits per vehicle class [13].

Stage	Date	CO	HC	NOx	PM	PN**	Smoke
		g/kWh				1/kWh	1/m
Euro I	1992, ≤ 85 kW	4.5	1.1	8.0	0.612		
	1992, > 85 kW	4.5	1.1	8.0	0.36		
Euro II	1996.10	4.0	1.1	7.0	0.25		
	1998.10	4.0	1.1	7.0	0.15		
Euro III	1999.10 EEV only	1.5	0.25	2.0	0.02		0.15
	2000.10	2.1	0.66	5.0	0.10*		0.8
Euro IV	2005.10	1.5	0.46	3.5	0.02		0.5
Euro V	2008.10	1.5	0.46	2.0	0.02		0.5
Euro VI	2013.01	1.5	0.13	0.4	0.01	8.0x1011	

*PM = 0.13 g/kWh for engines < 0.75 dm^3 swept volume per cylinder and a rated power speed > 3000 min^{-1}.

** PN: Particle number

Different contexts of LEZ: Rotterdam, The Netherlands

The first LEZ applied in Rotterdam was in 2007. A small area surrounding the city center in which the entry of heavy-duty vehicles of Euro III and lower was banned. Earlier registrations are not granted an entry to the zone, however there are some exemptions for which drivers can apply to gain limited access (up to 12 days per year). This heavy-duty ban was replicated again in 2014 around the city harbor (Maasvlakte Port LEZ) where a different scope of regulation was applied. Unless the vehicle had earlier registered to enter the zone; only Euro VI heavy-duty diesel, and/ or vehicles younger than 7 years can enter the harbor. Registered vehicles still need to apply for an exemption if they do not meet the specifications. Such strict regulation is only applied to lorries of 3.5 tons or heavier[7].

After proving its success in the urban area and considering the city's need to continue working on air pollution reduction, in 2016 the city-center LEZ was expanded both *geographically* and *regulatorily.* In addition to the previous heavy-duty vehicles ban, the 2016 policy banned the entry of diesel passenger cars and vans that are older than Euro III and Petrol passenger cars and vans older than Euro I. The new geographical boundaries expanded to include all the area encompassed by the ring-road above the river (See Figure 5) [7, 14].

Figure 5: Rotterdam's different LEZs boundaries 2007- 2016[14].

A different form of access regulation that is currently being applied in Rotterdam is the Lorry-free road ('s-Gravendijkwal[b] Lorry ban)[15]. This is a specific road closed to all kinds of logistics vehicles except for EVs. However, even for EVs, they cannot enter throughout the year, but only a certain number of days (to address congestion). EV owners apply to such limited access through an online application process[7]. Such type of restriction if applied alone cannot be identified as a LEZ, as it is limited in area and effect. Yet, it is helping in guiding the transition towards low-emission traffic.

Based on these standards, and on the number of vehicles per euro class in each city in addition to the targeted pollution reduction per phase, cities identify their restricted vehicles.

2.2.2 Geographic scope

Geographical locations and boundaries for the LEZs are set based on the initial air quality

[b] A name of a street in Rotterdam. The 's in 's Gravendijkwal is a genitive, meaning "belonging to". The original " 's Gravendijk" would be "des Graven(s) dijk" meaning dijk belonging to the Graaf (dike that belongs to the Earl).

Combining LEZs with toll roads and congestion charge: The case of Oslo

Oslo, the capital of Norway, can be considered one of the innovative low-cost adaptations of LEZs in Europe. LEZs in Oslo are controlled through main roads that have already existing monitoring cameras for congestion charging and road tolls. Following an occurrence of a critically high air pollution episode in Norway, in 2016 the national government created a fast act for transport and communication. Under this national act, cities that had high air pollution problems like Oslo were enabled to include LEZ within their existing legal frameworks[3].

Building on that, in 2017 Oslo applied congestion charges and increased its roads-toll scope to be differentiating according to vehicle emission classes, distance traveled, location and time of the day (See Figure 6). Through adding the environmental dimension to its framework, Oslo was able to have a LEZ as an easy low-cost measure[7,3].

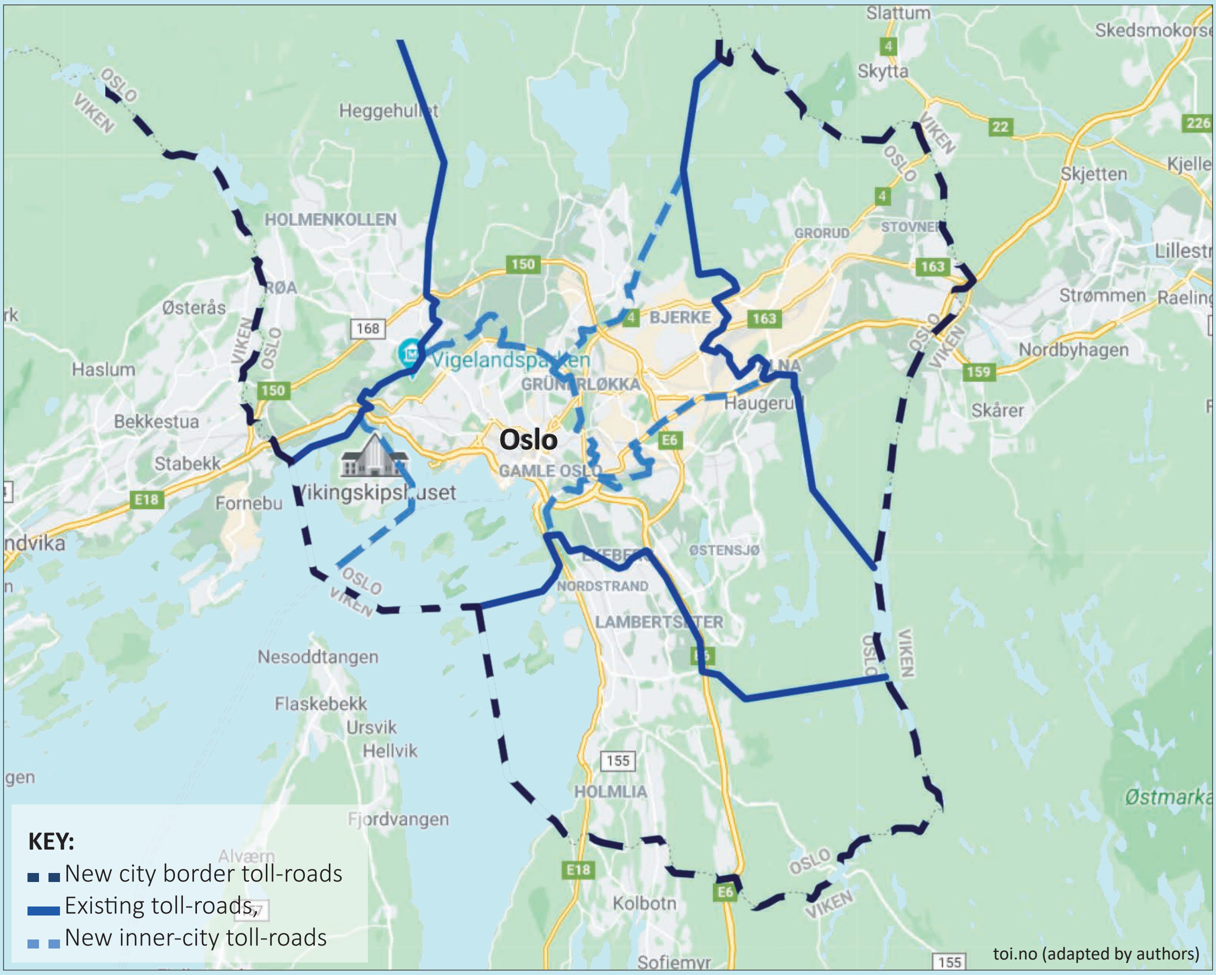


Figure 6: Oslo LEZ location and boundaries [3].

situation, the traffic needs, and the political status of the city. In most cases LEZs are highly polluted "areas" that are constrained by major streets (e.g. all that lies inside a ring-road boundary), it can be a district, a neighborhood, or an entire city. Nevertheless, LEZs sometimes are controlled through *major streets* only, excluding the intersecting connections. This means that polluting vehicles can stay within the side streets avoiding main roads that are characterized by high emission production.

2.3 Policy and planning contexts

The approach to implementing LEZs differ widely depending on the local contexts. Furthermore, implementation includes both physical and regulatory prerequisites. However, much guidance has now become available over the years to suit different contexts. Within the European Union, which is leading in this respect, there is an accumulation of LEZs practices and experience that today produced a flexible and adjustable framework for new cities to follow. This section includes the most significant prerequisites for LEZs from around Europe.

London's expanding scope of LEZs and Ultra-LEZs

As part of the Air Quality Strategy of 2008, London started its LEZs policy. The policy was coupled with the congestion charge measure that was applied since 2003. The LEZ however extended to cover an area much larger than the congestions charge zone. London's LEZ is identified as being the largest in Europe[5, 7, 16]. The city followed the carrot-and-stick strategy, where it provided sufficient incentives for vehicle replacement, partially financing by the LEZ revenues (LEZ entry fees and penalties)[16]. Other programs included in the 2008 Air Quality package are as follows[17,18]:

- Bus improvement program
- Taxi emission strategy
- Best practice guidance
- Controlled parking zone
- Better integrated transport

Since most air quality measures are associated with the transport sector, in 2017, the Mayor of London Sadiq Khan incorporated the existing LEZs (and the accompanying measures) under the city's larger and overarching strategies for transport and environment. Such strategies then included, a *Toxicity Charge*, an *Ultra-LEZ*, schemes for cleaning the bus fleet, introduction of the clean vehicle checker, introducing air quality audits at schools in the most polluted areas, and having all new registered taxis to be zero-emission capable[19]. The government worked on a generally well-supported policy package that can assist and speed up the emission reduction process, including provision of a reliable low-emission public transport network.

Overall, London's LEZ is continuously developing and expanding, while the city is constantly introducing new policies and more strict regulations based on air monitoring and forecasts (Figure 7).

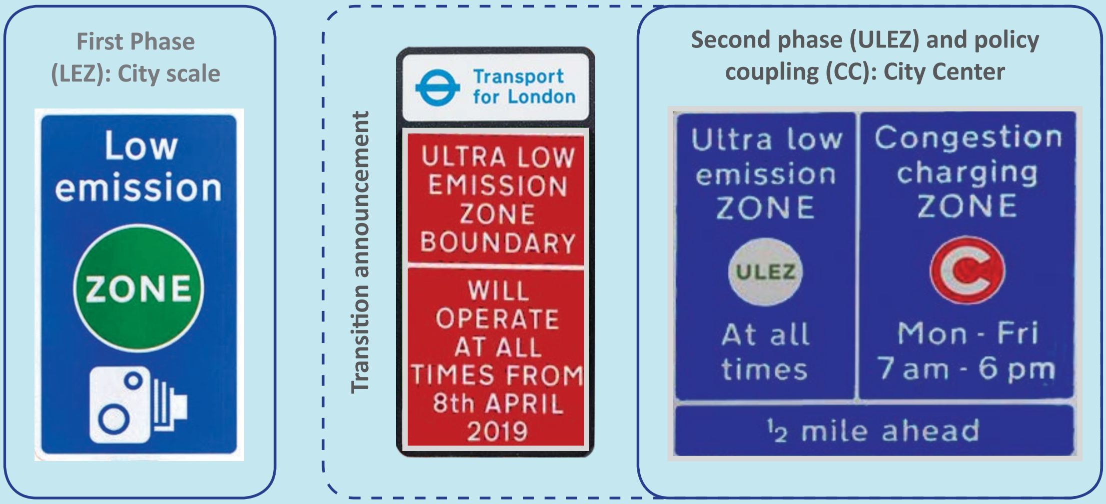


Figure 7: London's different street signs and policy phases indicating time and type of restriction.

2.3.1 Regulatory prerequisites and accompanying measures

As a general transport policy that affects different stakeholders, LEZs must be included under a national or a local agenda[3]. Since the policy targets the reduction of air pollution throughout the control over traffic emissions, it is usually included under the city's Traffic and/or Air-Quality agendas.

The agenda typically comprises short- and long- term visions, and the LEZs are accordingly implemented in stages. The early stage (less restrictions) provides credibility and a marketing advantage for the following stages (of more/ improved restrictions) and facilitates the long-term transition towards sustainable mobility at large[6,14, 20]. A city can introduce more than one LEZ with different restrictions; this can be based on land use, type of traffic, and zone pollution level[7]. It is crucial to identify and create awareness of the overall target and the timeline of policy application early before it starts (See Figure 4).

For successful implementation, best practices stress that transport policies such as LEZ schemes must always be planned as part of a larger package of guiding and accompanying measures that ensure its success and mitigate any adverse impacts[21],[22]. These measures differ based on the scope of restrictions, the city's context, and the overall target. Examples typically include old cars scrappage schemes, financial incentives for compliance, free or subsidized park-and-ride systems, inner-city speed reduction (traffic calming), boosting electric mobility, and congestion charging, among other regulations and measures.

2.3.2 Physical and digital infrastructure prerequisites

To initiate LEZs enforcement, governments must first assign a well-structured LEZ monitoring and evaluation system. Along with that, it is important to clearly set the zone boundaries and create awareness about the new system prior to its application. The three main prerequisites are: (a) information provision, (b) monitoring of violations, and (c) progress evaluation, each described as detailed below.

a. Information provision

Information provision feeds into the most social aspect of the policy application, which is the awareness creation. On the one hand, governments provide sufficient education about the policy, reasons for its application, and the benefits that come with it. Awareness campaigns are included in the short-term agenda and is applied in parallel to the policy (e.g. social evenings, newspaper, and street advertisements talking about the importance of having clean air, the status of the city, short- and long- term targets, and the usefulness of the LEZs). On the other hand, physical information provision must take place in the important location of the LEZ (e.g. street signage around the zone entrances, including information about the required vehicle specification). Finally, a web portal and online applications for the LEZ must be created to fully inform users. In the process, taking social aspects into consideration and ensuring stakeholder participation and engagement is essential to ensure smooth enforcement and reduce political risks or resistance and objections by different stakeholder groups.

1. Stakeholder participation and community engagement in Rotterdam, The Netherlands:

Rotterdam represents a very good example of a democratic city that takes very good care of community awareness and social inclusion in policymaking. On one hand, within the *Rotterdam Traffic Plan 2017-2030+* which included the LEZ as a policy measure, the city comprised several measures that work on information provision and awareness raising. Such measures involved different community events that can boost community participation through cooperation with the area committees, encouraging local initiatives, and communicating the air quality targets[23],[24].

Furthermore, earlier before the light-duty LEZ application, the city provided a 6-month grace period for drivers to adapt to the new system and identify whether their vehicle is

Figure 8: Different street signage. Images from left to right: License checkers, Camera location at LEZ entry[25], and floor signage[26].

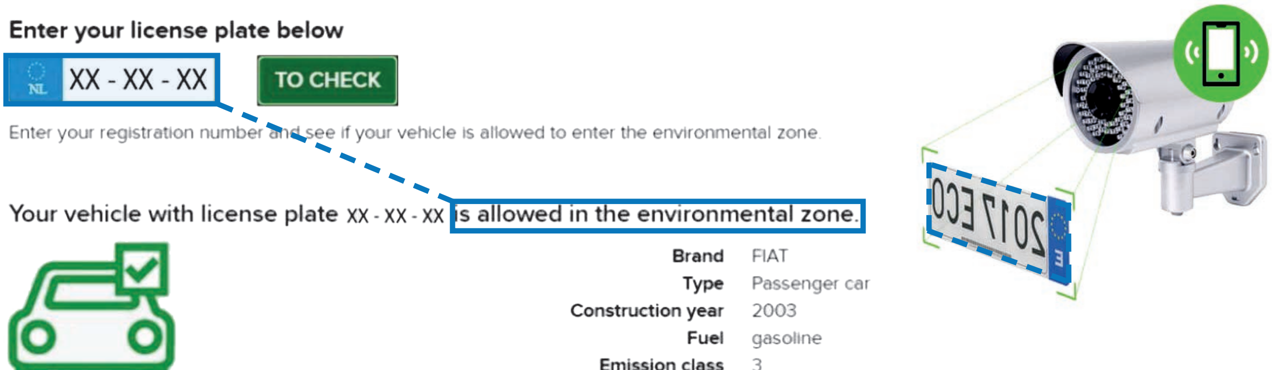
banned or not. Such information was provided through instant street license-checkers, online governmental websites, and mobile applications. Nevertheless, all along the LEZ activation, horizontal and vertical street signages are surrounding all LEZ entrances identifying which type of vehicle is banned from each zone (See Figure 8).

b. Monitoring violations

LEZs require continuous monitoring and control to verify their effectiveness. Such monitoring entails earlier system preparations. Different systems vary in their levels of control and requirements. There are however two very commonly used successful systems applied in Europe[3]:

1. Automatic number plate recognition (ANPR) (and camera surveillance)

Applied in countries like the Netherlands, Belgium, and the UK. There is a nation-wide database that includes all number plates registry and automatically detects car movement through both fixed cameras inserted around the zone entrances and mobile cameras that cover busy and major streets, which identify and process vehicle number plates (see Figure 9). This system is not only national for some countries, but also accessible for the neighboring countries too. ANPR had proven success in recording all movement to and within the LEZ. However, it requires a very accurate preparation of the datasets. The datasets typically include the following for each vehicle: *vehicle type, brand, type of engine, registry date, number plate, municipality of registry,* among other attributes, as necessary. Preparations also requires several cameras testing to ensure the accuracy of locations and positionings. The ANPR is very sensitive to privacy issues



www.rotterdam.nl & cmykdigest.com (adapted by authors)

Figure 9: ANPR system; ANPR Camera detection (right) and online information database (left).

and is centrally controlled by the national government to guarantee compliance with security and privacy regulations.

2. Manual control and stickers

Applied in Germany, and France (See Figure 10). Through adding a colored sticker on all nationally registered cars, officers manually assign violations to the zone-restricted colors. A common criticism of this approach is that it does not guarantee full control over violations as with ANPR. For this system to succeed, different authorities need to collaborate locally to manage it (e.g. police and traffic wardens). However, its advantage is that it requires less complicated preparations, includes fewer privacy issues, and it is easier to be implemented locally.

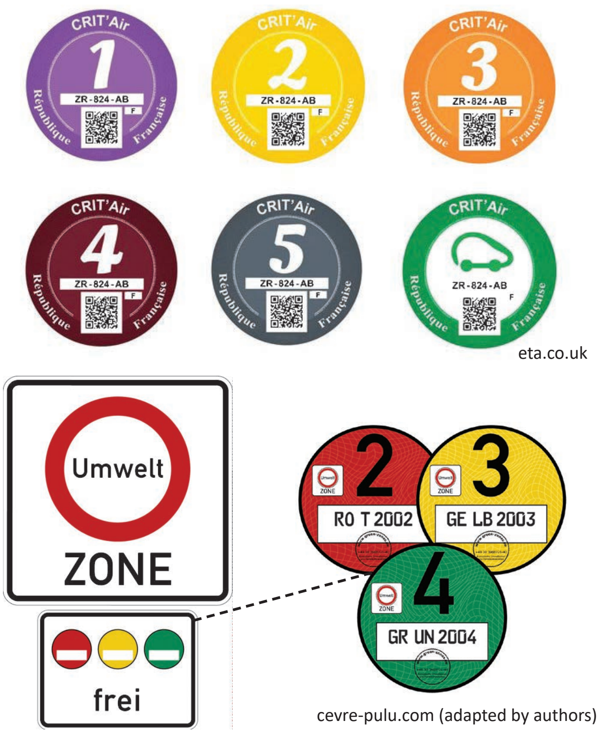


Figure 10: Manual control stickers examples of French stickers (UP) and German stickers and street sign(Down)

Since the LEZ is a strictly a context-based policy and is applied in countries of diverse nature around the world, not all countries are readily suited to apply same monitoring methods. If other usable databases existed, other methods can be used as well. For example, in some developing countries in Africa and Asia, road transport monitoring is done through *Radio-frequency identification* (RFID) stickers combined with pre-existing databases that might not necessarily include all the ideal sets of data for vehicles. Such a system can also be adapted to be used in identifying and controlling LEZs entries.

c. <u>Progress evaluation</u>

After setting the long- and short-term targets in the local agenda, the LEZs must be periodically evaluated based on these targets. The two applied evaluation methods are as follows:

1. Monitoring PM and NOX levels:

LEZs is an air pollution reduction policy; the most appropriate evaluation technique is through measuring and comparing the air quality levels and emission concentrations in locations inside and outside of the zone. It is therefore crucial to have specific locations for measuring the ambient air quality, set a clear numerical target, and acquire accurate measurements for the same locations before and during the policy application[16]. These measurements help in further publicity for the policy and in promoting public acceptance.

2. Counting car passages per type of engine:

For some countries, data about the air quality is not easily available, and monitoring devices were not set prior to the policy. In this case, evaluations are made based on the types of vehicles that enter the zone. Most countries that have the ANPR can depend on this type of evaluation. (e.g. In the case of Rotterdam, measurements are made through the same week annually. Cars are monitored by engine type in different locations inside and outside the LEZ. Numbers are compared to the previous years. Based on the fleet change, air pollution reduction is predicted[27].

2.4 Impacts

While emission reduction is the expected direct impact from LEZs, health improvement, social satisfaction, financial savings, and traffic reduction are expected as indirect impacts. Different studies were performed for testing the effect of LEZs on emissions, fleet composition and traffic reduction (depending on the scope of the policy). Yet accurately measuring the impact of this specific scheme on the actual health improvements, social and economic impact, etc., is often difficult. This difficulty of isolating the impact of LEZs separately is due to limited data availability as well as the vast complexity of having several other influencing factors at play, and also due to the various measures often made together in the larger strategies of cities [28], [29].

However, positive health, environmental, and economic impact are nevertheless observed in the improved local air quality levels, and the users' mode-switch towards active travel modes, especially for short trips, and public transport.

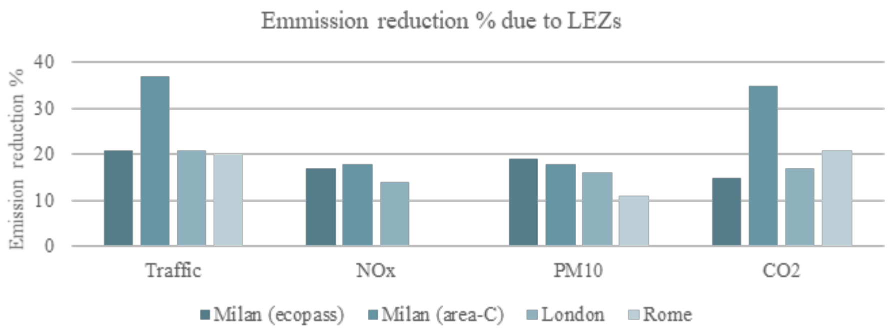
In terms of social impact (and *perceived* social impact), it is notable that different outcomes of the policy can occur. On one hand, the restrictions can raise many objections by various stakeholder groups and even lead to lawsuits that force the government to ease parts of the policy[30]. On the other hand, when the residents understand the reasons behind the restriction and receive proper communication on the results and policy progress, this can create a trusting relationship between the government and the residents. This is particularly the case among residents that are directly subjected to air pollution hotspots and suffer from location-based injustice.

Nevertheless, studies so far are mainly concerned with measuring the direct effect of LEZs on emission and traffic reduction. Table 2 demonstrates examples of different scopes of policy contexts and a comparison between their levels of pollutant reduction. The table illustrates that the Milan (area C) LEZ is the most successful one. This can be due to its different levels of restrictions, especially the addition of parking charges within the policy package[8]. It also suggests that despite the main target of LEZs, which was the reduction of NO_x and PM_{10}[3], the LEZs greatly affect CO_2 and traffic composition [8].

It is notable however, that the metrics used must be well understood in analysis. Reduction in pollution *emissions* from vehicles is favored, but the impact on ambient air pollution is the ultimate goal (i.e. ambient air pollution concentration in the city). This is a challenge for cities to measure and analyze and is in progress, especially with ongoing advancements in monitoring and analysis techniques.

Table 2: Different LEZs application scopes and impact [8].

	Milan	**London**	**Rome**
Area	71% of Milan	Most of London	About 5 Km2 Summed up
Type	LEZ (& CC)	LEZ (& CC)	LEZ (& CC)
Rules	CC & parking charge + access restriction	Pay to enter Or meet standard	CC & parking charge + access restriction
Banned Vehicles	- Up to Euro 4 diesel - No access for freight vehicles (8 am – 10 am) and bulky vehicles (Monday-Friday, 7.30 am to 7.30 pm)	< Euro 6 Diesel And <Euro 4 Petrol	Each zone has its own rules
Percentage of achieved pollutants reduction.			



2.5 Common pitfalls and considerations for developing countries

Like many transport policies, LEZs have many limitations and challenges and there is much room for policy improvement and development. The most challenging LEZ criticism relates to its relatively low impact on the reduction of PM_{10}, which was the policy's main target in the earlier days of the scheme's conceptualization. It was soon found however that LEZs have significant impact on NO_x, black carbon (BC), and CO_2 emissions, as well as traffic reduction. Thus, cities are readjusting their policy targets accordingly[31].

LEZs are also criticized for their harsh restrictions that affect different types of users (e.g. business owners, public transport, private-vehicles, motorists, vintage-car collectors) making it difficult to receive full public support. Countries that are newly adopting the policy must take into consideration how they will ensure public acceptance and what accompanying policies and measures will be introduced to mitigate the impact of the restrictions. Pitfalls to avoid are as follows:

2.5.1 Poor communication and stakeholder engagement

Observing hundreds of LEZs worldwide, it is evident that public acceptance always played a major role in the scheme's realization and continuity[32]. To ensure public acceptance and avoid resistance, cities must pursue the following decision-support steps[32]:

1. **Provide a pre-implementation proof of policy effect** based on traffic data modeling and on similar case studies.
2. **Clearly announce plans well in advance** to offer sufficient time (grace period) for users to adapt and to build trust.
3. **Announce well in advance the available alternatives** and market for future restrictions through the provision of better alternatives.
4. **Ensure evidence-based planning** by providing the science and data to back up the arguments, as well as monitor the policy effect i.e. through fixed emission monitoring stations inside and outside the LEZs and a disclosed before-and-after analysis of impact.
5. **Apply phased policy implementation** to provide room for different stakeholders to agree and for the policy to be adjusted through trial and error.

An example of how public acceptance can greatly influence the success of LEZs schemes is what happened in Rotterdam 2017. At some point in phases of implementation, after the LEZ was expanded to include *private* vehicles, large public protests occurred, and representatives (car owners represented by the Peoples' party) filed a lawsuit to stop such extension. Even though the government was able to showcase how the policy was successful in terms of air quality improvement, the regulations were eased in response to the social unrest[30].

It is notable that although the calculated number of restricted private vehicles was not large enough to negatively impact the air quality (it was mainly vintage cars), this policy withdrawal can hinder the city's transition towards zero emission mobility[23]. The example of Rotterdam's experience, which exemplifies many other experiences elsewhere, highlights the importance of adequate stakeholder participation at the earliest stages of planning and launching of LEZs schemes (or when initiating new phases of stricter regulations) in order to ensure successful implementation and public acceptance and endorsement.

Conversely, in the renowned successful case of London, the policy had been gradually phased-in since 2008, with adequate stakeholder engagement, as well as preceding relevant experience in congestion charging in 2003. In that LEZ case, private vehicles have not been excluded from the LEZs to date. The future plans to exclude private vehicles (for *Ultra-Low Emission Zones* or *Zero-Emission Zones*) are first being well disclosed, marketed, and discussed to respect and include people's needs and concerns.

2.5.2 Implementation without the adequate enabling policies and measures to provide alternatives

As mentioned in previous sections, the LEZ must fundamentally be part of a larger policy package that guarantees availability of alternatives for users. In such cases, it is advisable for developing countries to plan for alternatives for the different types of users.

A summary of guidelines is as follows:

1. Guide the bus and truck drivers effectively: When restricting Heavy Duty Vehicles (HDVs), the government can communicate (effectively) what other routes are still available for drivers to perform their duty until they can switch to a more sustainable vehicle. The same applies to other affected commuters.
2. Ensure availability of filters and technical assistance if required: If the city is allowing *retrofitting* (e.g. vehicles installing filters of various types to meet emission standards, such as Diesel Oxidation Catalysts, Diesel Particle Filters, and other types), they need to ensure the availability of the correct filters for all types of vehicles, and maybe incentivize the filter price and effectively provide necessary technical guidance.
3. Upgrade public transport, the feeder systems, and commuter experience (including walking to the station): When restricting private vehicles, the public transport network capacity and quality of service must be enhanced to accommodate the shift in mode choice and increased demand on public transport, and the safety, comfort, and enjoyability of the commuter experience. This includes feeder transport services and attention to last-mile commuter experience.
4. Park-and-ride facilities at all peripheral entrances: Park-and-ride facilities need to be enforced at all zone entrances and be well linked to the public transportation network.
5. Incentivize EVs (and other low-emission vehicles) and provide infrastructure as needed: If electric vehicles are allowed in the LEZ, then it is the government's duty to provide electric charging infrastructure within the LEZ boundaries, and similarly so for other low-emissions technologies. Furthermore, Incentivizing the purchases of electric vehicles (and other low-emission vehicles) is a very successful strategy that can reduce policy resistance and improve the new vehicle stock quality. However, introducing cleaner technologies should not be pursued without cleaning the existing stock (*repair, refurbish, repower, retrofit, retire*), so that policy *consistency* is ensured, and to avoid the mistake of simply introducing cleaner technology introduced to the existing polluting fleets. Scrapping is among such measures.
6. Scrap old vehicles: Scrapping and recycling schemes can be a very strong LEZ supporting policy, ensuring that the most polluting vehicles are not driven to other neighboring areas. This also stimulates the renewal of the vehicle stock and stimulates the local industry if available.
7. Consider exemptions as needed: Exemptions can be allowed to mitigate impact on specific vulnerable groups, such as exemptions up to a specific number of days per year (e.g. 12 days per year), or other forms of carefully planned exemptions.

Such measures can support the application of LEZs and nudge the user to accept its otherwise harsh restrictions. Other restrictions can also be applied to push drivers towards sustainable alternatives.

For example, parking restrictions, micro mobility infrastructure and traffic speed reduction policies (traffic calming) can be applied within the same LEZ boundaries[23]. Congestion charging has also proved its success if applied within the LEZ policy packages[8]. Yet again, all these policies need to be slowly phased-in, supported, and communicated with the stakeholders earlier before its applications.

LEZ in a megacity of a developing country: Beijing, China

The capital of China, Beijing, has for long been suffering increasing air pollution (See Figure 11). They are extensively studying this recurring crisis, testing policies, and applying various measures to address it[33]. Among such measures, in 2017, Beijing started its first LEZ that targets the ban of highly polluting HDVs (Vehicles below the National IV Standards) from driving in the urban area of Beijing [34], [35].

Figure 11: Beijing hazardous air pollution smog. December 2015.

The policy was introduced under the 13th Five-Year Plan for Urban Public Transport addressing traffic congestion and emission issues as part of the plan. The package included congestion charging, LEZs and parking fees as prioritized solutions, together with other transport demand management (TDM) measures to facilitate adaptation[35]. This was among various other measures to mitigate air pollution.

A key challenge for the government in this process was notably the adequate quantification of emission-reduction impact of different schemes to compare effectiveness of different approaches [33]. However, valuable methodology guidelines to address this challenge were developed as an outcome of this experience.

In 2018, the Chinese Ministry of Transport (MoT) worked with the World Resources Institute (WRI office in China) on developing a series of guidance documents that offer a methodological framework to develop an inventory for vehicle emissions [33, 32]. The reports also included different case studies from around the world, focusing on aspects like community acceptance, policy packaging, network evaluations, and provision of alternatives[32].

Among the highlights of the final report (See Figure 12), is that LEZs were suggested to be better suited to control particulate matter (PM) and nitrogen oxides (NOx), whereas congestion charging is more effective at reducing emissions of hydrocarbon (HC) and carbon monoxide (CO) [33]. This implies that both policies can successfully be coupled (or merged) together to achieve maximum emission reduction while banning only the most polluting vehicle[33].

Figure 12: WRI Final report[33]

3. SITUATION ANALYSIS: EGYPT

3.1 Air pollution priorities

The hotspot in terms of air pollution in Egypt is primarily the Greater Cairo Metropolitan Area, followed by other cities of large and dense populations and increasing vehicle ownership. Besides the monitored data on air pollution from the extensive network of the Egyptian Environmental Affairs Agency, the pollution is also at a level that is commonly visible to the untrained eye, such as on vegetation and buildings.

Rice straw burning has been a key culprit of air pollution along with open burning of waste, but this is in gradual decline with the successful efforts of the competent authorities.

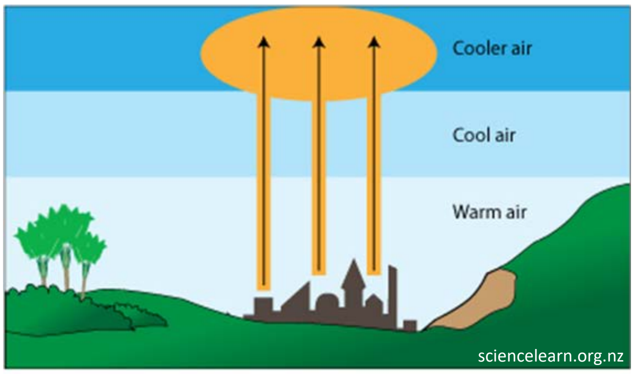
However, the following two pending challenges continue to pose the greatest threat to any progress in this respect:

a. <u>Thermal inversion episodes:</u>

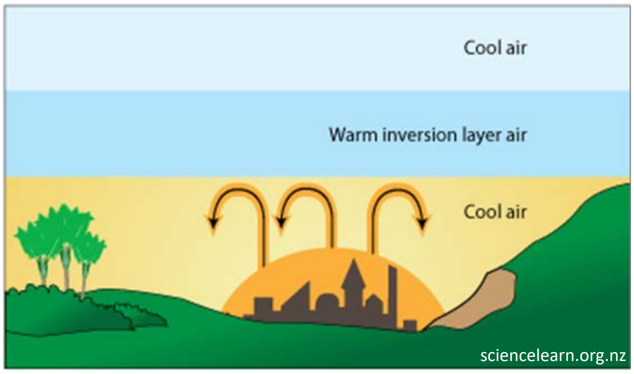
Meteorological phenomena can sometimes exacerbate (magnify) the existing pollution, specifically due to the formation of a thermal inversion layer (or ‘temperature’ inversion) commonly experienced in the autumn season in Greater Cairo. This can also occur in other times of the year. In a simplified explanation, if this layer forms at lower altitudes, the concentration of trapped air pollution shall be even higher. The thermal inversion layer altitude is therefore an important factor (mixing height). Even if earlier culprits of air pollution such as rice straw burning have been addressed, the existing air pollution from vehicles and other sources will still continue to accumulate in such conditions and continue to cause a ‘black cloud’. This phenomenon is further explained in the following sections (section 2.1.1.)

b. <u>Diesel fuel quality:</u>

The diesel fuel in Egypt (colloquially known as ‘soular’) has a Sulfur content that is more than 100 times above the global acceptable levels[36]. This is not only a concern due to Sulfur Oxides (SO_x) emissions, but also because this contaminant prohibits the use of emission control devices in the heavy vehicles that use it (e.g. Diesel Particle Filters and Diesel Oxidation Catalysts), leading to uncontrolled release of other pollutants as well. Gasoline, however, is of comparably acceptable quality.



Normal pattern



Thermal inversion

Figure 14: Thermal inversion formation involves a warm air layer trapping a cooler air layer along with air pollution entrapped[37].

Thermal inversion is clearly a natural phenomenon, but it can be predicted so that suitable precautionary measures are taken in cities, such as in the following list of selected examples:

- Temporary management of emission sources (e.g. temporary partial vehicle restrictions, limiting industrial production, etc.)
- Sending notifications through schools, sports clubs, and multimedia (such as announcing in weather forecasts), to inform both the general public and different sensitive groups,

to avoid outdoor physical activity, temporarily close outdoor football fields, etc.

- Plan for crisis management and adequate capacity of medical care services, etc.

Inter-ministerial cooperation is therefore fundamental (coordinating measures associated with public health, environment, industry, etc), together with deeper understanding of the phenomenon and its impact.

3.1.1 Thermal inversion trapping air pollution

Thermal (or temperature) inversion is a meteorological phenomenon. In normal or typical conditions, the air in the atmosphere is found to be naturally cooler with altitude. However, sometimes an *inversion* occurs whereby a layer of the atmosphere becomes warmer. This creates a layer that traps the cooler air beneath, along with air pollution if present, and this is an undesired *stable* condition that can result in accumulation of air pollution in cities.

Later, the return of the favorable unstable conditions (winds/breeze ventilating the city at a *macro*-scale) allows the pollution to disperse once more, and for the air to return to the regular temperature profile of steady cooling with increased altitude (see Figure 14).

Trial of Air Quality Index Disclosure in Tahrir Square, 2008

The first attempts to explicitly develop and disclose an Air Quality Index (AQI) was in 2008 with the establishment of the Tahrir Air Quality Monitoring Station in Tahrir Square (above Omar Makram Garage) with support of the Japan International Cooperation Agency (JICA)[c]. In this brief experience, the AQI was displayed on a large LED screen for the first time (See Figure 13), in a manner accessible to the layman; a series of emojis of varying colors indicated the level of pollution in real-time. The concept was discontinued for various reasons, including vandalism in the events of 2011, uncertainty about sustaining the social marketing activities and assessing impact, as well as needs for capacity building for the sake of institutionalizing the concept and expanding the scope beyond the demonstrational purpose.

Figure 13: AQI display screen in Tahrir Square. Image credit: Sally Elfishawy.

[c] This background is provided by the author who was part of the expert team implementing this project as part of the Regional Environmental Management Improvement Project (2006-2008) for the capacity building of EEAA and its regional branch offices.

3.1.2 Global examples for the thermal inversion phenomenon

There are many examples of cities where thermal inversion coincides with the prevalence of air pollution from a city. Inversion layers are a significant factor in the formation of smog (visible air pollution) in Los Angeles for example, which is known for suffering this episodic stable atmospheric condition at times. This inversion inhibits mixing in the lower regions of the troposphere and thus exacerbate the formation of smog. This is resolved when the temperature profile returns to normal, cooling steadily with elevation.

During critical episodes' this phenomenon can be easily observed by an untrained eye looking at a dense city from a distance and sufficient altitude when smog is present (See Figure 15).

The understanding of this association between inversion layer formation and smog has for long been advanced since studies dating as far back as in the 1950s and earlier, such as in the prominent examples of the London Smog, or the recurring smog in the city of Los Angeles, which continues to face this challenge to date[38].

Early warning systems for high air pollution episodes associated with thermal inversion formation are therefore fundamental to plan response and preemptively implement emission reduction measures.

However, long-term emission reduction is essential for an overall reduction in severity of such events. In the case of Egypt, this implies addressing major concerns: Open burning of wastes along with uncontrolled vehicle emissions associated with hazardous diesel fuel quality, considering its high Sulphur content.

3.2 Implications of critically high-Sulphur in fuel

Studies on air pollution have for long been advocating various important measures that can be offered by innovative technologies like electric vehicles, or alternative fuels such as natural gas, etc. However, when put into proper perspective and a foreseen timeline, the impact of *fuel quality* improvement on air quality is found to be by far a much higher priority[45], and a prerequisite to many other measures:

> *Current trends suggest that the slow penetration rate of electric vehicles (and natural gas vehicles) in Egypt will not be sufficient alone to improve air quality in the coming years if there are no parallel measures to improve emissions from existing vehicles and their fuels; especially diesel fuel; the primary priority for air quality improvement.*

Figure 15: Los Angeles photochemical smog and the common visual display of distinct layers, November 2016[39]

Table 3: The evolution of EU fuel specifications for Sulphur content[40]

Implementation Date	Name	EU Directive	Sulphur Limit (ppm)
Oct. 1996	Euro 2	93/12/EEC	500 (diesel)
Jan. 2000	Euro 3	93/12/EEC	350 (diesel); 150 (gasoline)
Jan. 2005	Euro 4	98/70/EC	50*
Jan. 2009	Euro 5	2003/17/EC	10, 10**

* 10ppm fuel must be available
** nonroad fuels limit

One of the most critical challenges in attempting to reduce vehicles' sulfur emissions is that, high contents of Sulphur results in inhibiting the performance of the vehicle emission control devices (average exceeding 2000ppm, in Egypt, i.e. orders of magnitude higher than acceptable levels).

For reference, the common benchmark in Egypt is the European emissions limits Standard, which has set limits to Sulphur content in diesel fuel at 50ppm (Euro 4) since 2005, and 10ppm (Euro 5) for the past decade as noted in Table 3.

The pursued potential leapfrogging to adequate standards is however a matter of estimating costs involved on one hand, and the benefits to the sector and *society* on the other hand. This involves valuation of externalities of pollution (e.g. eliminated costs of health deterioration, environmental degradation, impact on tourism, etc).

In this respect, the global strategy for Sulphur reduction championed by the Climate and Clean Air Coalition (CCAC) Heavy Duty Vehicles Initiative of UN Environment provides that the benefits exceed the costs. In its 2016 *Global Strategy to Introduce Low-Sulfur Fuels and Cleaner Diesel Vehicles*, the initiative developed studies based on countries that have not yet established 50ppm fuel sulfur standards, the results indicated that desulfurization of on-road fuels by 2050 would results in global benefits that outweigh costs at a ratio of 16:1, clearly justifying any government investments necessary[46].

A fundamental implication of reducing Sulphur is that the benefits are not limited to reduced SO_x emissions, but also to a host of other harmful emissions. Once Sulphur is reduced to adequate levels, there is then the possibility to introduce emission control devices that control other emissions as well. This is further explained in the following section.

WHY SULPHUR REDUCTION?

According to the World Health Organization (WHO), approximately one in eight global deaths in 2012 were a result of air pollution exposure, making this the world's single largest environmental health risk (Figure 16).

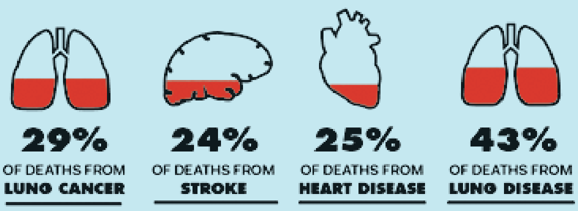


Figure 16: Implications and risks of highly polluted air.

The International Agency for Research on Cancer has classified diesel engine exhaust as carcinogenic to humans (Class 1). Nearly half of the above mentioned early mortalities are associated with outdoor air pollution. The main cause is fine particles ($PM_{2.5}$). Vehicles are significant sources of $PM_{2.5}$ and in many cases the major source.

To reduce $PM_{2.5}$ emissions from vehicles there is an urgent need to introduce low-Sulphur fuels – fuels with no more than 50 parts per million (ppm) Sulphur, and ideally ultra-low 10 or 15 ppm Sulphur. Low-Sulphur fuels are also necessary for the introduction and effective operation of cleaner vehicles and emission control technology. This combination of cleaner fuels and vehicles will have major health benefits and deliver substantial climate benefits through the reduction of short-lived climate pollutants (i.e. black carbon).

Source: CCAC 2016, Global Strategy to Introduce Low-Sulphur Fuels and Cleaner Diesel

3.3 When can we start using emission control devices in vehicles?

Sulphur greatly impacts the performance of emission control devices in vehicles and is a catalyst poison, and therefore compromises the control of the following exhaust emissions of concern:

- Particulate Matter (PM), a complex diversity of suspended pollutants
- Hydrocarbons (HC)
- Nitrogen Oxides (NO_x)
- Sulphur Oxides (SO_x)
- Ozone (O_3) (due to the reaction of NO_x and HCs under sunlight)
- Carbon Monoxide (CO)

Two common and widely diffused emission control devices for diesel vehicles are Diesel Oxidation Catalysts (DOC) and Diesel Particulate Filters (DPF), whereas both require low Sulphur levels to function effectively.

1. **Diesel Oxidation Catalysts (require <500ppm):**

   Sulphur levels of 500ppm and below enables the introduction of vehicles equipped with Diesel Oxidation Catalysts (DOC), which can also be used as a retrofit solution for older vehicles. It is the most commonly used emission control technology after Exhaust Gas Recirculation (EGR). DOCs oxidize carbon monoxide (CO), gaseous and aerosol hydrocarbons (HCs) into carbon dioxide and water and improve combustion of the soluble organic part of carbon particles that comprise soot and smoke. A DOC can achieve a 20-50% reduction in total PM, and over 90% reduction in CO and HC[41]. Lower Sulphur is necessary for optimal performance.

2. **Diesel Particle Filters (require <50ppm):**

   Sulphur levels below 50ppm enable Diesel Particulate Filters (DPF) to be introduced and can also be a convenient retrofit option, but not for older vehicles. It greatly reduces particulate matter that can exceed 90%, and also reduces HC and CO. This level is needed to avoid damage to emission control systems in Euro-IV vehicles and above. Euro-IV vehicles however generally are not equipped with particulate filters. Euro-VI on the other hand, are 'filter-forcing' standards, i.e. require particulate filters[41]. Retrofit programs can be conducted to facilitate such a transition.

Many cities have indeed resorted to retrofit options, together with improved fuel quality mandates, such as Mexico City, Santiago de Chile, and Hong Kong, among others[41]. As an example that may be relevant for Egypt, Mexico initiated the transition through an initial pilot retrofitting program in cooperation with the US EPA, and involved import of ultra-low sulfur diesel (ULSD) fuel that was not yet available locally. This later prompted the state oil company PEMEX, to proceed in accelerating the transition towards producing ULSD together with retrofitting programs to mainstream emission control device requirements[42],[43].

Availability of compatible diesel fuel (low-Sulphur) is therefore fundamental to the introduction of emission control.

3.4 Historical Opportunity to address the diesel quality crisis in Egypt

On October 27th, 2020, Egypt's largest refining complex upgrade project was inaugurated under the auspices of the president of Egypt. The project is constructed by the Egyptian Refining Company within the existing Mostorod Petroleum Complex (MPC) northeast of Cairo. This upgrade resulted in a significant contribution to Egypt's local production capacity of diesel fuel. Among other products, an annual amount of 2.3 million tons of Euro 5 diesel fuel is now produced. This provides for about 15% of Egypt's diesel fuel demand.

Such upgrade has been a long-awaited capacity increase that will enable the discussion of setting standards for diesel fuel in Egypt (as highlighted repeatedly in studies throughout preceding years).

The challenge in introducing low-Sulfur diesel in Egypt has for long been the lack of sufficient local production capacity and the dependence on aging refineries producing low quality products that are used despite their hazards. This challenge has not been adequately addressed due to the perceived economic constraints and challenges in reforming the sector. The Egyptian refining industry was the earliest in the Arab region with the establishment of the first refinery in Egypt in Suez in 1913, still in operation today producing sub-standard products. Together with other similar old refineries, the quality of the products includes high-Sulphur diesel and is consequently threatening public health.

However, with recent increase in capacity, although supply may be still insufficient for nationwide coverage of low-Sulphur diesel (or ULSD), it is nevertheless possible to supply for Greater Cairo. Building on that, it is now possible to discuss the possibilities of implementing a cities-first approach in eliminating hazardous diesel fuel, with the logic of starting with the most vulnerable region; Greater Cairo[44],[45].

3.5 Cities-First Approach for Cleaner Fuels

In global transitions towards cleaner fuels, the 'cities-first' category is for countries pursuing cleaner fuels through prioritizing more stringent fuel standards in specific cities that are most exposed to air pollution first (or specifying certain transit corridors). For these prioritized cities/corridors, local availability of cleaner fuels is ensured first, and afterward, plans are set in-place to roll out the standard to the rest of the nation.

Countries that started with a 'cities first' approach include Argentina, Brazil, and Peru, among others, focusing on highly populated/dense areas first[46].

In this respect, and building on CEDARE's 2018 study on refineries in Egypt and fuel quality, and further considering the recent increase in capacity in 2020, the following key conclusions are today valid for implementation:

1. **Enforcing Euro-5 diesel fuel standards (or comparable low-Sulfur specifications) in Greater Cairo** as a first phase (given the availability of Euro-5 diesel fuel quantities today produced by advanced refineries) and establishing a new low-Sulfur standard for diesel fuel (the current specifications allow hazardous levels of Sulfur).
2. **Enforcing Nation-wide Euro-5 diesel standards** throughout all Egypt upon availability of sufficient quantities (i.e. through new refinery projects, desulphurization (Sulphur removal treatment) of the products of old refineries, and prohibiting import of high-Sulphur diesel fuel to enable meeting 2030 targets). Notably, costs of health and environmental damage are greater than the costs of desulphurization measures according to international studies.
3. **Incorporating costs of damage to health and environmental degradation into policy development processes.** The World Bank studies on the damage costs of air pollution (sector note of 2013) indicated that Egypt incurs substantial costs due to damage to health from air pollution, reaching approx. 1% of GDP[47]. This valuation would further increase if additionally considering impact on tourism, agriculture, historical monuments, climate change, and the quality of life in general, whereas vehicle emissions alone contribute to about one third of air pollution in Egypt.

Such measures shall coincide with the currently ongoing penetration of compressed natural gas (CNG) vehicles in Egypt along with the slower penetration of electric vehicles as well.

A vision and national strategy for cleaner fuels and vehicles is therefore required to ensure a holistic approach and to assert political commitment. A committee for fuels in vehicles emissions is already in place in Egypt to enable such a process.

3.6 Committee for Fuels and Vehicle Emissions

The discussion of fuel quality from the environmental and public health perspective is led by the Ministry of Environment (MoE) through its executive arm, the Egyptian Environmental Affairs Agency (EEAA). In this respect, a ministerial decree was issued in 2017 to establish a committee for the study of reduction of emissions from domestic consumption of petroleum products across sectors. The committee is chaired by the Central Department for Air Quality and Noise of EEAA, and includes the Egyptian General Petroleum Corporation (EGPC) and Egyptian Organization for Standardization (EOS) as well as other key stakeholders including the Ministry of Transport (MoT) and public transport authorities' representatives, the Federation of Egyptian Industries (FEI), Federation of Egyptian Chambers of Commerce (FEDCOC), and the Industrial Development Agency (IDA), Ministry of Finance (MoF), Ministry of Health and Population (MoHP), Ministry of Local Development (MLD), Ministry of Interior (MoI), and Cairo University.

The mandates of the committee can be re-visited however to explore whether it enjoys sufficient authority to meet such foreseen obligations for LEZs strategy and action plan development. This primarily revolves around setting legally binding safe fuel quality standards and establishing emission-based vehicle classification, along with the other prerequisites of LEZs.

3.7 Air Quality Monitoring and evaluation challenges

Ambient air quality (and associated weather data) monitoring in Egypt is mainly characterized by (1) An established network of monitoring stations, and (2) an ongoing practice of disclosing air-quality related information online and use for early warning.

1. **Air quality monitoring stations:**

   There is a wide network of air quality monitoring stations in Egypt, which support the Egyptian Environmental Affairs Agency (EEAA) monitor ambient air pollution. A key challenge, however, is in the limited analysis of data and integration with other data sources, as well as linking the monitoring results to its practical implications and follow-up interventions, such as lining up standard procedures for crisis response or informing long term decisions and plans like imposing certain vehicle access regulations, etc.

2. **Air quality forecast (online) and early warning (simplified processes):**

   Proxies for air quality forecasts are currently communicated to the public through the EEAA website[48]. What is actually indicated is based on the *weather* conditions. Specifically indicating the *ventilation index*, which is seen as a proxy for indicating areas where air pollution *might* be of concern if coinciding with inversion layer formation. Future prospects include the ambition to provide information based on actual air pollution concentrations measurements and forecasts, rather than meteorological conditions. This is subject of ongoing planning and improvement.

   Among the challenges of the current state of affairs, is the difficulty in establishing before-and-after evaluation of the impact of various air pollution reduction measures, such as LEZs, or of fuel quality standards, etc.

   In this respect, future prospects for improving monitoring are most notable in a recently launched project of the World Bank, *Greater Cairo Air Pollution Management and Climate Change project.* The project substantially supports the air quality and GHG monitoring and management capacity of EEAA. The support is done according to needs assessment and addressed in its first project component; Enhancing the *Air Quality Management & Response System*. In this respect, an alignment with the vision of implementing Low Emission Zones may be of interest. Other future prospects include potential collaboration with the Egyptian Space Agency (EgSA) to explore possibilities for employing the emerging Egyptian space program for environmental purposes.

Space Tech, Artificial Intelligence (AI), and the future of air quality management

Among the globally emerging solutions to provide timely and relevant air quality monitoring data and decision support, is the use of space technology and AI-enabled data analysis. With advances in space technology and AI applications, it is possible to have ever more informative output that was not formerly attainable. Examples include:

- Real time identification of pollution sources when anomalies are observed,
- Analysis of the influence of wind on air quality measurements,
- Inversion layer monitoring,
- Association with traffic data,
- Improved monitoring, prediction and ability to factor in more influencing factors.
- Satellite observation data further enables prediction from a spatial perspective the dispersion of air pollution in areas where no sensors are installed.

Out of the produced satellite observations, the resulting heatmaps and analysis of air quality (both real time and forecast) are of great usefulness. An example for that is the approach most recently developed by Space Tech company *Hawa Dawa*, leveraging open *European Space Agency* (ESA) data to demonstrate potential capabilities (See Figure 17). This can be used in planning response measures, prioritizing policies, or for evaluating impact of government interventions and regulations, after correcting for weather and wind influences (e.g. before and after expanding bus systems, setting fuel quality standards, shifting technology to natural gas or electricity-powered fleets, vehicle scrapping schemes, Low Emission Zone schemes, etc).

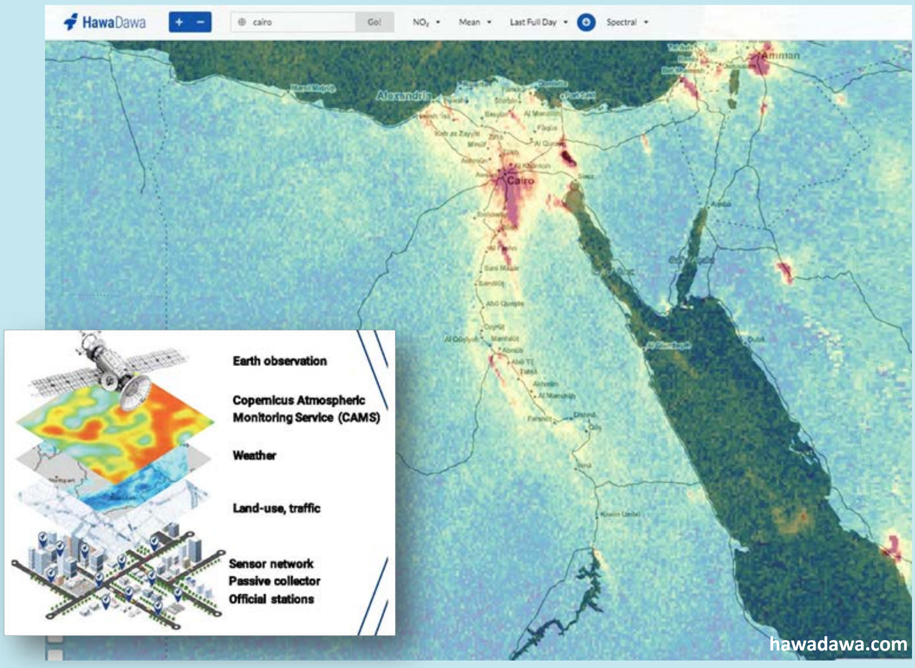


Figure 17: A screenshot of an animated display of pollutant concentration changes throughout Summer 2019 (Illustrations courtesy of Hawa Dawa, provided here for illustrative purposes only).

Components of such systems are today already deployed in more than 26 European cities, supported by the German government and the European Space Agency (ESA), including the cities of Munich, Zurich, Bern, and Belfast, among many others.

3.8 Progress and limitations in vehicle monitoring and data management

Currently vehicle databases in Egypt at the Ministry of Interior (MoI) are predominantly for administrative purposes and not sufficiently accounting for the technical specifications of vehicles. However, with the advent of electric vehicles, and the need to upgrade the databases to accommodate a wider range of technologies, it is foreseeable to cease the opportunity and expand the database of vehicle attributes. This shall be done in order to facilitate data analysis and monitoring that serves environmental purposes, fleet renewal, and energy saving, etc. but it essentially requires the political will to develop the needed databases.

3.8.1 Egypt's Vehicles RFID tags

Other than the ongoing shift towards formalizing the licensing of electric vehicles (still in progress at the date of writing this report), there is also a shift towards equipping all vehicles with a form of tracking devices. This is specifically in the form of *Ultra High Frequency (UHF) RFID tags* (stickers) that are being gradually rolled out since 2019[49] (See Figure 18). The existence of a strong RFID system may promise the facilitation of certain measures that involve remote sensing and surveillance capabilities, i.e. imposing congestion fees, automatic toll collection, Low-emission zones, or other similar interventions. Automated Number Plate Recognition (ANPR) is also undergoing gradual rollout in parts of the country.

However, to date, there is limited availability of accessible vehicle technical data other than those required for licensing already in place (e.g. engine size) and no categorization by emission class.

Figure 18: Example of an RFID sticker placed on vehicle windshields in Egypt

The timeline for rolling out RFID tags is not certain. Accordingly, short- and medium-term solutions to developing UVARs and LEZ schemes must consider such limitations.

3.9 Social and political risks

Among the most challenging aspects of enforcing emission regulations is the implication on poorer segments of society. Many are dependent on the affordable old and worn-down vehicles that are allowed on the streets to date in Egypt, in light of the limited enforcement of emission standards. This poses a challenge in respecting the principles of sustainable development goals (SDGs), which emphasize attention to vulnerable groups.

(SDG) Goal 11:

> *Make cities and human settlements inclusive, safe, resilient and sustainable.*

Target 11.2:

> *By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons.*

-UN Resolution 70/1

For many families, the affordability of such vehicles allows for affordable trips to school, education, employment, commercial activities and more. This is especially the case when considering the common entrepreneurial practices of carpooling and using vehicles for commercial activity as well, or for filling in gaps in public transport provision, as there are no borders in informalities with regards to vehicle uses and functions, and there is also further status (cultural) value of vehicle ownership at risk[50].

Gradual change is therefore necessary in any enforcement efforts, combined with safety-net measures, such as facilitating alternatives for poorer segments of society and affected stakeholders, as well as ensuring effective communication of regulations, guidance messaging, and time for compliance.

Figure 19: Child boarding the informal 'Dawra' service in an informal settlement, typically a sub-standard 9-seat private diesel-powered or gasoline-powered van, which is also used for other purposes at other times of the day as well.

The following is an explanation of such concepts:

- Impact mitigation: Examples of impact mitigation measures include generous grace periods for scrapping aging vehicles, and designing fair replacement schemes with financial incentives, along with the ongoing improvement in infrastructure and public transport provision. However, clear communication about such mitigation measures is key.
- Communication: Communication alone can alter the *outcome* of social impact mitigation measures. For example, if certain a restriction (e.g. banning the use of diesel vehicles without emission control devices) within cities is imposed, a parallel communication of the suitable mobility alternatives and the available roads shall be provided.

Although part of mitigating impact of restrictions is to provide the parallel improvement of alternatives (e.g. improved public transport services and pedestrian infrastructure), these actions must however be communicated as such, i.e. framed as *compensation* measures.

Furthermore, deliberate communication and framing of a trade-off concept to the public mitigates the risk of perceived adverse net-impact and raises awareness about sustainable alternative choices and lifestyle adjustments.

Additional to the ambient air pollution concerns, exposure of individuals specifically during commuting has been highlighted in international studies as a significant concern, including the case of Greater Cairo[51]. This shed further light on the topic of disproportionate vulnerability of commuters in big cities, and such research supported development of guidance for protecting vulnerable groups of society, specifically children, with practical implications for other vulnerable groups[52].

Ringfencing revenues from restriction schemes is a common example of ensuring mutual reinforcement between restrictions on one hand, and social impact mitigation measures on the other; scheme revenues can be reinvested into measures for reinforcing the scheme and mitigating its social impact.

3.10 Health vulnerability, resilience, and COVID-19

Another set of vulnerable groups and segments of society are those that are vulnerable in terms of health, and which will most benefit from measures for air pollution mitigation. This includes elderly people, children with uncontrolled asthma in poor families, pregnant women, and other people suffering other respiratory of cardiovascular diseases. Disadvantaged communities (e.g. in informal areas) are at higher risks of impact of air pollution, and therefore, emission mitigation may largely benefit such vulnerable groups these of course, besides all residents in the core of Greater Cairo (as a high-risk area).

'Ringfencing' as a message of coherent policymaking

A practical example of ensuring this direct association between the proverbial 'carrot' and 'stick' is the concept of *ringfencing* revenues from enforcement schemes (e.g. fines, congestion fees, levies, etc) in order to channel them specifically into associated mitigation measures that reduce impact on poorer segments and facilitate alternatives. As an example, revenues can be ringfenced and reinvested to:

- Softening loans for vehicle replacements,
- Compensating for scrapped vehicles,
- Investing in local bus stations upgrades,
- Subsidizing transport costs for certain groups (e.g. schoolchildren)
- Financing awareness initiatives promoting sustainable mobility

Such incentives should ideally be time-bound, as revenues are expected to diminish with time (the main objective is that behavior eventually changes and enforcement scheme revenues diminish), so the scheme is designed for a specific transition period. This is an effective measure that has also been employed in other fields of sustainability such as in the transition towards a circular economy and mitigating impacts of excessive consumerism[53].

" …My visits to the doctor have been cut by half once I moved to the outskirts of Cairo in the Fifth Settlement, and I need my medications much less now and I breathe much better now"

-Testimonial by former resident of Cairo's Central Business District[d]

Furthermore, the advent of the novel coronavirus pandemic, COVID-19, further strengthens the argument and emphasizes the urgency for mitigation of local air pollution emissions.

Exposure to high air pollution has been indeed found to increase risks of complications in treatment and recovery and may confound the impact of COVID-19, and a correlated exposure to higher air pollution has been also associated with higher rates of mortality[54,55].

3.10.1 Costs of health damage already high before COVID-19

A list of key references that attempted to support the valuation of the damage of air pollution in Egypt are enlisted as follows (while higher costs are expected in future studies post-COVID-19):

- WB (2002) study, highlighting air pollution as the highest contributor to damage costs in Egypt among all environmental pressures[56].
- WB (2013) study, calculating health and environmental degradation costs attributed to air pollution in Greater Cairo to be an average of 1.03% of GDP over the period of 1999-2009[57].
- Lowenthal et al. (2014), Source Apportionment Study indicating that 21%- 37% of air pollution is attributed to Motor Vehicles[58].
- WHO (2016) data, estimating air pollution costs equivalent to a great loss of life years equivalent of DALYs (*Disability Adjusted Life Years*); estimated as 2,162 DALYs/1000 inhabitants. This is globally ranked in the lowest quartile of countries with highest estimations of losses. The *DALY* is a metric used to estimate the equivalent years of a *healthy* life lost due to the burden of disease.

[d] Quote retrieved from interviews by authors conducted with anonymous interviewees in Cairo for indicative purposes.

4. WHAT TO DO IN PARALLEL TO LEZS?

Building on global experiences, the priorities in measures to be implemented in Egypt as either *prerequisite* or *parallel* measures are as follows:

- Low-Sulfur diesel fuel availability (a prerequisite in the case of Egypt, to allow installation of emission control devices)
- Public transport and shared services enhancement.
- Urban Vehicle Access Regulations (UVARs) at large (i.e. further to those associated with emission control such as parking schemes, pedestrian zones, congestion charging, etc).
- Improved land-use planning to ensure the move towards *compact* and *mixed-use* developments that reduce transport demand and enable non-motorized mobility.
- Cycling, Pedestrianization and Traffic Calming interventions.
- Conservation of (and promoting) trees and urban vegetation, to capitalize on the various ecosystem services they provide, and conservation of heritage, which contributes to enjoyable walkability.
- Reinforcing citizen participation in planning and implementation.

4.1 Status and gaps

Some of the accompanying policies and measures to enable successful LEZ implementation are already in progress at some level in some areas in Egypt. Most notably, the growing awareness about the need for public transport in Egypt has brought the topic to the forefront of transportation planning already and is evident in the ongoing megaprojects for public transport provision including rail transport of various types, the vast investments into expanding bus systems, and the improvement of the quality and capacity of the enabling road network.

However, a remaining challenge is the attention to the other fundamental elements of sustainable cities, including greenspace and public space in general, heritage conservation, adequate pedestrian infrastructure (including cycling infrastructure, and road safety in residential areas, etc.), as well as the cross-cutting prerequisite of citizen participation that must be insured throughout all such interventions.

4.2 Well-being of nature, trees, and urban biodiversity

The well-being of nature and trees has for long been protected through the Egyptian Penal Code[59].In this respect, a penalty of *jail sentence* is imposed on acts of damaging or cutting trees (Article 367 of the Egyptian Penal Code), indicating the longstanding position of Egyptian law towards protecting the environment[60, 61].

Criminality of cutting trees: The Egyptian Penal Code

...A penalty of penal servitude shall be inflicted upon:

First: *Whoever cuts down or destroys non-harvested plants of trees planted or grown by nature, or such other plants.*

Second: *Whoever damages a sown field or spreads noxious and harmful plants in a field.*

Third: *Whoever uproots one of more trees or any other plant, cuts therefrom, or peels them, in order to destroy them, and also whoever destroys a graft in trees.*

The felons may be put on parole by police for a period of at least a year and at most two years.

-Article 367 of the Egyptian Penal Code

Furthermore, such considerations are implicitly incorporated into the requirements of Environmental Impact Assessments (EIA). In the meantime, there is a continuous effort to ensure higher coverage of enforcement and awareness to meet the goals of such laws and regulations.

However, a key challenge in developing countries, and in megacities such as Cairo is the expansion of road networks as an intuitive response to traffic congestion. In this respect, the management of green cover is challenged by the lack of monitoring and evaluation, as well as the lack of enforcement for the existing regulations protecting the urban environment. Whether in the form of trees or other softscape in the city, public gardens and green roofs, any type of green cover provides substantial benefits as follows:

- Air pollution mitigation
- Collective function as a 'carbon sink',
- Mitigation of *heat island effect* (and associated improved comfort as well as reduced air conditioning energy consumption)
- Improved aesthetics, quality of life, and 'humanizing' cities and neighborhoods
- Improved comfort, including function as shading elements (in the case of trees), and contribution to the pedestrianization of streets through improved experiences.
- Habitat for urban wildlife.
- Heritage value (the abundant assets of old trees in Egypt of historical/heritage value further to functional value), as well as neighborhoods identity and placemaking functions, among other functions and ecosystem services.

In this respect, enhanced mainstreaming of softscape conservation (or expansion) in urban development projects largely supports the suitable sustainable urban environment that must be ensured in parallel to LEZ development. Among the means to mitigate impact on green cover is mainstreaming conservation measures in Environmental Impact Assessment (EIA) studies and in their mitigation plans. This is especially important for EIAs in the *transport sector*, which impact public spaces most.

The EIA process includes development of a plan for minimizing and mitigating of identified impacts and is further supported through the integration of stakeholder consultation (citizen participation) throughout the studies.

4.3 Environmental Impact Assessment and Citizen Participation in Transport

As per Law No. 4 of 1994 for the protection of the environment, and its later amendments, projects of different scopes must be subject to Environmental Impact Assessments (EIAs) before construction/implementation. This includes social impact assessments and stakeholder consultations in principle.

Not all projects require the same level of depth and width of scope in EIA studies, so there are 3 classes of EIAs to differentiate the scope:

- **Class-A,** for limited-impact projects such as small capacity food production facilities, restaurants, small metalworks or carpentry workshops, simple public garages, etc. The EIA is conducted through filling a provided form.
- **Class-B,** for medium-impact projects, such as printing houses, medium/large production facilities for electronics, dairy products, small hospitals and clinics, agricultural recycling faxcilities, etc. The EIA is conducted through filling a provided form.
- **Class-B 'Scoped'** is a further sub-classification for class-B projects that need specific in-depth studies for component of the project based on terms set by EEAA.
- **Class-C,** for high-impact projects, such as cement plants and national mega-projects like ports and power plants, etc. A 'full' EIA is accordingly conducted.

Each class has an indicative list of projects that are categorized as such. The list is issued by the Ministry of Environment.

In 2016 certain changes were conducted, which have in some cases been a concern of certain environmental organizations due to risks posed by limited control over impact-mitigation and risk-mitigation obligations of project developers.

This is a topic that is subject to further possible discussions in the future, in order to continually and gradually reconcile the needs of economic growth (which require facilitating project development speed) on one hand, with the needs of longer-term environmental sustainability and public health on the other hand.

Reconciling differences can be in the form of gradually introducing special conditions and guidance to address key impact categories (e.g. impacts on groundwater quality and flow, impacts on residential areas' pedestrian safety and green cover, or construction-phase impact mitigation for residential areas, etc).

Currently, the situation is as indicated in Table 4. This indicative list demonstrated a move towards breaking down transportation projects into more categories, starting from roads that are up to 5km being assigned Class-A categorization. Formerly, "internal highways in cities" was classified as Class-C, and notably without indication of size limits, while no transport system projects were in the lax categories of Classes A or B.

The concern communicated by environmental organizations, activists, and NGOs, is over the extent of impact that 5km roads can have in urban areas, which might require further consideration in the future developments of laws, regulations, and guidelines.

Examples of considerations include impact on ground-water flow, construction-phase pollution such as dust and impact on neighboring communities, schools, hospitals, etc, and impact of clearing the green cover including old trees, and public gardens, etc.

In the case that consideration of concerns of residents are not adequately taken (e.g. conservation of public spaces, road safety and pedestrianization, etc), this can result in deterioration of urban settlements and therefore difficulty in ensuring the shift toward sustainable mobility options and lifestyles in an increasingly harsh urban environment (see Figure 20).

Expansion of means for citizen participation, such as through existing laws and regulations and EIA guidelines and requirements, or foreseeable amendments, are therefore favorable for the transition towards sustainable cities.

Table 4: Changes made in 2016 updating the classes of EIAs required for different projects in transport, indicating that road pavement projects of up to 5km can be made with class-A EIA requirements (future prospects are to expand the definitions).

	2009 classification	2016 classification
CLASS-A	-	**(54) Road pavement (up to 5km)***
CLASS-B	-	(161) Railway construction (length up to 50 km) (162) Road Construction (length up to 50km) (163) Paving main roads and side streets (length more than 5km) (166) Public garages of more than 200 cars (with maintenance services)
CLASS-B, SCOPED	-	(54) Construction of roadways of length up to 100km (56) Railway lines construction (length up from 50 to 200km) (57) Renovating existing railway lines.
CLASS-C	(59) Large transportation system and high-ways including the underground metro, bridges, and tunnels. **(60) Internal highways in cities.** (61) Railway lines.	(55) New urban communities projects / residential cities development. (56) Railway lines construction (length of more than 200km)

*A challenge worth discussion is that a 5km road in a residential area can have much higher impact potential on people (in the case of cities) compared to certain 100km roadways in the desert, which therefore implies a need for different metrics for such categorization.

Figure 20: Developments in Abdelaziz Fahmy street in Cairo, exemplifying challenging tradeoff that often favors road construction at the expense of other elements of sustainability (incl. public space, walkability, cycling-friendliness, thermal comfort, urban greenery and wildlife, road safety, and clean air).

Highlight: The Heat Island Effect

A heat island is an urbanized area experiencing high temperatures compared to surrounding less urbanized areas. This occurs as buildings, roads, and other infrastructure absorb and re-emit the sun's heat. Among several coincidental side-benefits of green cover in cities is the mitigation of this effect, thus improving comfort and reducing energy consumption for cooling, among other impacts.

The contribution of green cover to the comfort and enjoyability of the urban environment is a key factor in facilitating the switch to public transport, cycling, and walking, and adapting to policies that rationalize use of private cars.

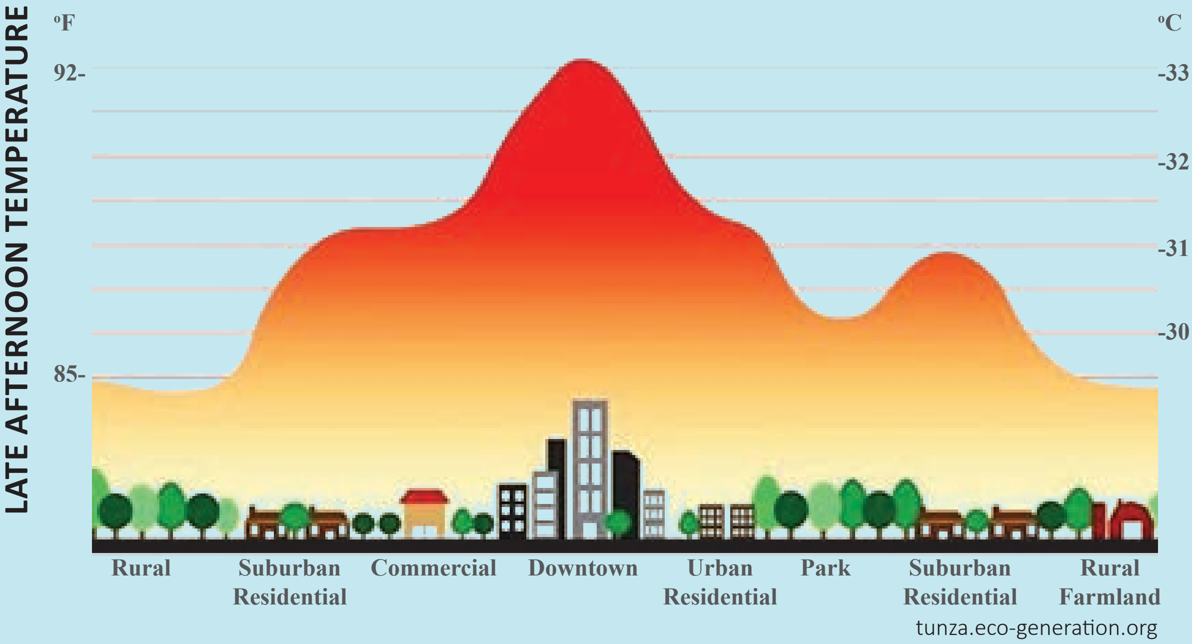


Figure 21: Typical variation in temperatures in cities experiencing a heat island effect

5. CONCLUSION AND RECOMMENDATIONS FOR PLANNERS

Throughout the development of the policy paper herein, extensive consultation sessions and interviews have been conducted with key stakeholders to arrive to recommendations that are tailored to the context of Egypt, and building on previous work of relevance.

Among the key opportunities for progress is the recent development of an overarching organization for transport planning in Egypt in 2019 to consolidate strategic sustainable mobility planning, *The Land Transport Regulatory Authority (LTRA).* It is mandated to oversee transport planning and regulation in Egypt.

Figure 22: Provision of parking places dedicated to low-emission vehicles in one of Egypt's new LEED-certified commercial centers.

Furthermore, substantial advancement is also foreseen over the next years in terms of the Ministry of Environment's plan to upgrade air pollution monitoring, management, and early warning systems capacity and capabilities. In the meantime, there have been recent advancements and upgrades in the refining industry that may allow provision of cleaner fuels, since a major root cause of air pollution is associated with high-Sulphur diesel fuel.

With such developments and potential, it may be possible today to pursue city-wide schemes for improving air pollution through tailoring *Low-Emission Zones* concepts to local contexts.

In this respect, and with reference to international best practice and current situation analysis in Egypt, the recommendations are summarized as follows, starting with fundamental elements and prerequisites needed and building towards the bigger picture.

5.1 SHORT-TERM (IMMEDIATE) MEASURES [2021-2022]

- **Low-Sulphur (Euro-V) Diesel fuel standards *(Cities-First approach)*:** Introduce diesel fuel quality standards as per the roadmap of the cities-first approach for low-Sulphur diesel fuel (for Greater Cairo deemed of high vulnerability) through direction by the Ministries of Environment and of Health, and with assigned responsibilities to the Ministry of Petroleum, to jointly meet Egypt's 2030 sustainability targets. Existing refinery upgrades in progress enable meeting such a target.

- **Scheme for cleaner Heavy-Duty Vehicle (HDV) fleets retrofitting/replacement:** Develop schemes to support environmental compliance of heavy-duty vehicles to meet minimum requirements of installing filters (or leaving the filters installed), as compatible low-Sulphur fuel is introduced, and develop the regulatory framework to ensure the continuity of the scheme.

- **Establish a unit for *Sustainable Urban Mobility* in the LTRA,** to enable and build capacity for mainstreaming low-emission zone planning and advancing coordinated Urban Vehicle Access Regulations (UVARS), as well as integrating environmental attributes in activity licensing data in the LTRA databases and vehicle technical data (ideally integrated with the database of the Ministry of Interior on the longer run)

- **Use existing/ongoing momentum:** Although an LEZ scheme is not in place, various enabling elements for LEZs are already identified in Egypt and can be leveraged to accelerate the scheme planning and rollout (i.e. ongoing upgrades in management through RFID monitoring of vehicles, expansion of tolling systems and gradual automation, introduction of pilot camera surveillance and ANPR facilities, existing UVARS managing access of certain trucks in certain circumstances, advancements in rollout of CNG-powered vehicles, experience in vehicle scrapping schemes, etc).

5.2 MEDIUM-TERM MEASURES [2021-2024]

- **Vehicle Emission Standards for HDVs (priority) followed by other vehicle classes:** Introduce internationally recognized vehicle emission standards (euro standards as the most popular reference/benchmark among competent authorities) with a plan for phasing-in such standards and capacity to monitor. Subsequently, introduction of standards for other vehicle types is due (LDVs, etc).

- **Revisiting EIA regulations/guidance for road projects:** Revise Environmental Impact Assessment (EIA) requirements for transportation projects to protect cities to be aligned with the priorities of conservation of public space and green cover in the city, as well as heritage. This implies addressing the challenge that a road construction project of up to 5 kilometers can currently be implemented *without* a thorough EIA process (i.e. only the simplest *class-A* process; lowest requirements in Egyptian categorization), while expanding the scope of mitigation measures to favor sustainable mobility. This aims to secure *friendliness* of the urban environment for pedestrians (safety, comfort, enjoyability), as well as for cyclists and public transport users in their last-mile trips, and to enable commuters to shift from private cars towards diversified mobility behavior choices.

- **Develop a roadmap and action plan for LEZ scheme development for Greater Cairo,** this may involve investigating the various scenarios to meet the ultimate targets for air quality improvement, conducting policy impact assessment (social, environmental, economic), investigating scenarios for various stages/zones/administrative areas, or piloting certain Urban Vehicle Access Regulations (UVARs) such as restrictions on high-polluters in certain areas, in parallel to ongoing cleaner-fleets schemes in process.

  For *indicative* purposes, Annex-1 presents orientation about example-scenarios for the sake of initiating discussions and highlighting the key questions that competent authorities must attend to. Although Greater Cairo is identified as the priority urban area, other cities may introduce schemes in advance or in parallel, whether existing congested polluted cities or new urban communities including the new capital.

- **Safety-net measures:** Throughout roadmap and action plan development, measures to mitigate impact on vulnerable groups are essential. Examples include facilitating mobility alternatives for poorer segments of society and affected stakeholders. This is already partially available in Egypt in various forms such as discounted rates/ packages in public transport, while future prospects may additionally include improved pedestrianization (safety, comfort, etc) in the urban environment, as well as compensation of vulnerable groups such as poorer segments of passenger-car owners and microbus owners that may be heavily impacted by new restrictions on aging and polluting vehicles. Revenues from LEZ schemes may support such mitigation measures (ring-fencing revenues for social impact mitigation measures).

- **Impact evaluation and advanced analysis techniques:** Evaluate impact of ongoing schemes and overall progress based on ambient air pollution concentration monitoring and improved analysis of data, including making use of ongoing advancements in using satellite data, artificial intelligence, and improved integration with traffic data for improved accuracy, relevance, and efficiency for continual evaluation and improvement.

5.3 MEDIUM-/LONG-TERM MEASURES [2021-2030]

Recommendations for medium- to long-term measures are as follows:

- **Nation-wide Low-Sulphur (Euro-V) diesel fuel provision,** complimenting the gradual penetration of electric and CNG vehicles.

- **Nation-wide deployment of LEZ schemes in priority cities:** Expanding LEZ schemes to other cities based on adequate evidence-based prioritization, and continuous evaluation of impact and improvement.

Furthermore, with regards to social marketing and communications planning, an advisable cross-cutting theme across all activities and interventions is the need for such planning to guide how the measures will be framed and communicated to the public, how acceptability and engagement shall be ensured, and how to respond to people’s concerns and feedback in an institutionalized manner, which according to international experiences has been key to success.

REFERENCES

[1] Larsen, Bjorn. 2019. Egypt: Cost of Environmental Degradation: Air and Water Pollution. The World Bank.

[2] Talaat, H., Abdelgawad, H. (2018). Mobile Monitoring of Black Carbon Levels and Development of Exposure Surfaces Reflecting Traffic-Related Air Pollution: The Case of Cairo. 98th Annual Meeting of the Transportation Research Board.

[3] Amundsen, A.H. and Sundvor, I., 2018. Low Emission Zones in Europe: Requirements, enforcement, and air quality. Available at: https://www.toi.no/getfile.php?mmfileid=49204 [Accessed 26-10-2020].

[4] European Commission, 2016. European strategy for low-emission mobility. Swd, 244pp. 13. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52016DC0501&from=en#footnote1 [Accessed 29-04-2020].

[5] Holman, C., Harrison, R. and Querol, X., 2015. Review of the efficacy of low emission zones to improve urban air quality in European cities. Atmospheric Environment, 111pp. 161-169. Available at: https://www.sciencedirect.com/science/article/pii/S1352231015300145 [Accessed 05-05-2020].

[6] Rapaport, E., 2002. The Stockholm environmental zone, a method to curb air pollution from bus and truck traffic Transportation Research Part D: Transport and Environment, 7(3), pp. 213-224.

[7] European Commission, 2020. Urban Access Regulations in Europe. Available at: https://urbanaccessregulations.eu/low-emission-zones-main/what-are-low-emission-zones#where [Accessed 2020].

[8] Kua, D., Bencekria, M., Kimb, J., Leec, S. et al., 2020. Review of European Low Emission Zone Policy. Chemical Engineering, 78Available at: https://www.researchgate.net/profile/Madiha_Bencekri2/publication/340574018_Review_of_European_Low_Emission_Zone_Policy/links/5e9171d0299bf130798fb5e5/Review-of-European-Low-Emission-Zone-Policy.pdf [Accessed 1-11-2020].

[9] Ohlmann, F. 2019. Riding in Italy: what is ZTL and how to avoid fines in town. Available at: https://italyonmotorbike.com/2019/12/09/riding-in-italy-what-is-ztl-and-how-to-avoid-fines-in-town/ [Accessed 22-11-2020].

[10] Transport for London, 2020. Transport for London: Ultra Low Emission Zone. Available at: https://tfl.gov.uk/modes/driving/ultra-low-emission-zone [Accessed 2020].

[11] Pieters, J., 2017. Fewer old, polluting diesel cars on Dutch roads; 73 pct drop since 2010. NLTimes, July 4,. Available at: https://nltimes.nl/2017/07/04/fewer-old-polluting-dieselcars-dutch-roads-73-pct-drop-since-2010 [Accessed 1-06-2020].

[12] Ezeah, C., Finney, K. and Nnajide, C., 2015. A critical review of the effectiveness of low emission zones (LEZ) as a strategy for the management of air quality in major European cities. Journal of Multidisciplinary Engineering Science and Technology, 2(7), pp. 1860-1868. Available at: http://www.jmest.org/wp-content/uploads/JMESTN42350921.pdf [Accessed 05-05-2020].

[13] DieselNet, ECOpoint Inc. 2019. Heavy-Duty trucks and bus engines. Available at: https://dieselnet.com/standards/eu/hd.php [Accessed 23-11-2020].

[14] Municipality of Rotterdam. 2015. Schone lucht, voor een aantrekkelijk en gezond Rotterdam 2015-2018. (Koersnota).

[15] Word references forum. Available at: https://forum.wordreference.com/threads/s-avonds.2566377/ [Accessed 23-11-2020].

[16] Ellison, R.B., Greaves, S.P. and Hensher, D.A., 2013. Five years of London's low emission zone: Effects on vehicle fleet composition and air quality. Transportation Research Part D: Transport and Environment, 23pp. 25-33. Available at: https://www.sciencedirect.com/science/article/pii/S136192091300059X [Accessed 05-05-2020].

[17] Frank J. Kelly & Julia Kelly, 2009. London air quality: a real-world experiment in progress, Biomarkers, 14:sup1, 5-11. Available at: https://doi.org/10.1080/13547500902965252 [Accessed 1-11-2020].

[18] Frank J. Kelly, 2008. Policies to improve air quality in London Frank Kelly. Achieving Sustainable Air Quality for London, King's College London. Available at: http://www.londonair.org.uk/london/asp/LAQNSeminar/pdf/jan2008/Policies_To_Improve_Air_Quality_in_London_Frank_Kelly_KCL.pdf [Accessed 1-11-2020].

[19] Domini, A. and Chicot, J., 2018. Mission-oriented R&I policies: In-depth case studies Clean Air London (UK). Luxembourg: European Union. Available at: http://www.jiip.eu/mop/wp/wp-content/uploads/2018/10/GB_Clean-Air-London_BirdTuerk.pdf [Accessed 1-11-2020].

[20] Müller, J. and Petit, Y.L., 2019. Low-Emission Zones are a success-but they must now move to zero-emission mobility. Transport & Environment: Brussels, Belgium.

[21] Givoni, M., 2014. Addressing transport policy challenges through policy-packaging. Transportation Research Part A: Policy and Practice, 60pp. 1-8. Available at: https://www.sciencedirect.com/science/article/pii/S0965856413002000 [Accessed 06-05-2020].

[22] Mingardo, G., 2008. Cities and innovative urban transport policies. Innovation, 10(2-3), pp. 269-281. Available at: https://www.tandfonline.com/doi/abs/10.5172/impp.453.10.2-3.269 [Accessed 16-04-2020].

[23] Attia, M., 2020. The effect of the Low-emission Zones policy and the Rotterdam Traffic Plan on the usage of alternative modes of transport: The case study of Rotterdam. Available at: https://www.researchgate.net/publication/344329243_The_effect_of_the_Low-emission_Zones_policy_and_the_Rotterdam_Traffic_Plan_on_the_usage_of_alternative_modes_of_transport_The_case_study_of_Rotterdam [Accessed 1-11-2020].

[24] Rotterdam, G., 2017. Smart accessibility for a healthy, economically strong, and attractive Rotterdam: Rotterdam urban traffic plan 2017- 2030. Rotterdam: Gemeente Rotterdam. Available at: http://tdamobility.org/wpcontent/uploads/2018/11/Rotterdam_Urban-Traffic_Plan.pdf [Accessed 03-04-2020].

[25] Harry, 2016. Rotterdam: Low Emission Zone. Available at: https://www.flickr.com/photos/harry_nl/26581741225/in/photostream/ [Accessed 2020].

[26] ANWB, 2019. Milieuzone Rotterdam wordt opgeheven. Available at: https://www.anwb.nl/verkeer/nieuws/nederland/2018/juni/milieuzone-rotterdam-wordt-opgeheven [Accessed 2020].

[27] Stelwagen, U. and Eijk, A., 2018. Rotterdam wagenparkscan 2.0, juni 2017. Rotterdam: TNO. Available at: file:///C:/Users/Owner/Downloads/TNO-2018-R10167%20(4).pdf [Accessed 01-08-2020].

[28] Tobollik, M., Keuken, M., Sabel, C., Cowie, H. et al., 2016. Health impact assessment of transport policies in Rotterdam: Decrease of total traffic and increase of electric car use. Environmental Research, 146(April 2016), pp. 350-358. Available at: https://www.sciencedirect.com/science/article/pii/S0013935116300147 [Accessed 05- 02-2020].

[29] De Nazelle, A., Nieuwenhuijsen, M.J., Antó, J.M., Brauer, M. et al., 2011. Improving health through policies that promote active travel: a review of evidence to support integrated health impact assessment. Environment International, 37(4), pp. 766-777. Available at: https://www.sciencedirect.com/science/article/pii/S0160412011000341 [Accessed 07-06-2020].

[30] Council, R., 2018. Case against the environmental exemption of Rotterdam 2016: 201705992/1. Available at: https://www.raadvanstate.nl/uitspraken/@7297/201705992-1-a2/ [Accessed 30-07-2020].

[31] Cyrys, J., Peters, A., Soentgen, J. and Wichmann, H., 2014. Low emission zones reduce PM10 mass concentrations and diesel soot in German cities. Journal of the Air & Waste Management Association, 64(4), pp. 481-487. Available at: https://www.tandfonline.com/doi/full/10.1080/10962247.2013.868380 [Accessed 08-11-2020].

[32] Wang, Y., Ye, F., Qiu, S., Song, S. et al., 2018. International Case Studies on Public Communication and Consultation Strategies for Low Emission Zones and Congestion Charging Schemes. Available at: https://files.wri.org/s3fs-public/international-case-studies-public-communication-and-consultation-strategies-low-emission.pdf [Accessed 08-11-2020].

[33] Liu, Y., Cheng, Y., He, W., Zhao, J. et al., 2018. Evaluation on Air Pollutants Reduction Effects of Beijing Low Emission Zone and Congestion Charging Policies. Available at: https://8eee4c46-e05f-49e4-a80e-84eda95c5ac7.filesusr.com/ugd/021d92_5294801c33b14fbabe1440e31282cee6.pdf [Accessed 08-11-2020].

[34] Zhang, Y., Andre, M., Liu, Y., Wu, L. et al. , 2018. Evaluation of low emission zone policy on vehicle emission reduction in Beijing, China, Anonymous [IOP Conference Series: Earth and Environmental Science]. IOP Publishing. pp. 052070.

[35] Wang, Y., Qiu, S., Zhao, T., 2018. Fewer emissions, better life: Beijing Low Emission Zone Final Report. Available at: http://www.indiaenvironmentportal.org.in/files/file/CIFF_Beijing%20LEZ%20Storybook.pdf [Accessed 08-11-2020].

[36] El-Dorghamy, A., Medhat Y. (2019). Policy Brief: Cleaner Fuels for Cleaner Air – Towards Cleaner, Low-Sulfur Diesel Fuel. Center for Environment and Development for the Arab Region and Europe (CEDARE) and UN Environment. , available at http://web.cedare.org/wp-content/uploads/2020/11/Refineries-Policy-Brief-Final.pdf

[37] University of Walkato (2020). Temperature Inversion. Science Learning Hub. https://www.sciencelearn.org.nz/images/1883-temperature-inversion

[38] Robinson, E. (1952). Some Air Pollution Aspects of the Los Angeles Temperature Inversion. Bull. Amer. Meteor. Soc. (1952) 33 (6): 247–250. https://doi.org/10.1175/1520-0477-33.6.247

[39] Britannica (ND). Smog: atmosphere. https://www.britannica.com/science/smog [Accessed on 25-2021]

[40] Transportpolicy.net (2018). EU: Fuels: Desel and Gasoline. https://www.transportpolicy.net/standard/eu-fuels-diesel-and-gasoline/ Accessed on Feb. 10, 2019.

[41] Partnership for Cleaner Fuels and Vehicles [PCFV] (2008). Opening the Door to Cleaner Vehicles in Developing and Transition Countries: The Role of Lower Sulphur Fuels. Available at https://www.unenvironment.org/resources/report/opening-door-cleaner-vehicles-developing-and-transition-countriesthe-role-lower. Accessed on Dec. 20, 2018.

[42] Kubsh, J. (2017). Diesel Retrofit Technologies and Experience for On-road and Off-road Vehicles. Prepared for International Council on Clean Transport. https://theicct.org/sites/default/files/publications/Diesel-Retrofits_ICCT_Consultant-Report_13062017_vF.pdf

[43] EMBARQ / WRI Center for Sustainable Transport (2007). Cleaning up the fleet: Case study from Mexico City [presentation in US EPA archive]. https://archive.epa.gov/international/air/web/pdf/cleaning_up_the_fleet.pdf

[44] El-Dorghamy, A. (2019). Policy Breif: E-mobility in Egypt + Updates. Center for Environment and Development for the Arab Region and Europe (CEDARE) and Friedrich Ebert Foundation Egypt. http://library.fes.de/pdf-files/bueros/aegypten/15389.pdf

[45] El-Dorghamy, A., Medhat Y. (2019). Policy Brief: Cleaner Fuels for Cleaner Air – Towards Cleaner, Low Sulfur Diesel Fuel. Center for Environment and Development for the Arab Region and Europe (CEDARE) and UN Environment.

[46] CCAC (2016). A global strategy to introduce low-sulfur fuels and cleaner diesel vehicles. Heavy Duty Diesel Initiative of the Climate and Clean Air Coalition. https://ccacoalition.org/en/resources/global-strategy-introduce%C2%A0low-sulfur-fuels-and-cleaner-diesel-vehicles, accessed: Nobember 2, 2020.

[47] WB (2013). The Arab Republic of Egypt For Better or for Worse: Air Pollution in Greater Cairo, A Sector Note. Report No. 73074-EG. World Bank Sustasinable Development Department, MENA Region. http://documents.worldbank.org/curated/en/972321468021568180/Egypt-For-better-or-for-worse-air-pollution-in-Greater-Cairo-sector-note

[48] Egyptian Environmental Affairs Agency (2020). Air Quality Forecast [webpage]. http://www.eeaa.gov.eg/en-us/topics/air/airquality/airqualityforecast.aspx, accessed: November, 15, 2020.

[49] Solutions, K. (August, 14, 2020). RFID Vehicle Identification Nationwide Vehicle Identification with UHF RFID in Egypt. RFID & Wireless IOT. https://www.rfid-wiot-search.com/kathrein-solutions-nationwide-vehicle-identification-with-uhf-rfid-in-egypt, accessed: October 22, 2020.

[50] El-Dorghamy, A. (2018). Children's Potential Mobility and Appropriation of Transport Options in and Informal Settlement: A Case Study of Ezbet El-Haggana. Doctoral Thesis. Faculty of Mathematics and Natural Sciences II, Institute of Geography, Humboldt University in Berlin. http://dx.doi.org/10.18452/19549

[51] Abbass, R.A., Kumar, P., El-Gendy, A., 2020. Car users exposure to particulate matter and gaseous air pollutants in megacity Cairo. Sustain. Cities Soc. 56, 102090.

[52] Kumar, P., Omidvarborna, H., Barwise, Y., Tiwari, A., 2020. Mitigating Exposure to Traffic Pollution In and Around Schools: Guidance for Children, Schools and Local Communities. pp. 24, https://doi.org/10.5281/zenodo.3754131

[53] UNEP (2018). Single-use Plastics: A Roadmap for Sustainability. [54] IZA – Institute for Labor Economics (2020). Deregulation in a Time of Pandemic: Does Pollution Increase Coronavirus Cases or Deaths? http://ftp.iza.org/dp13231.pdf, accessed: November 1, 2020.

[55] Coker, E.S., Cavalli, L., Fabrizi, E. et al. (2020). The Effects of Air Pollution on COVID-19 Related Mortality in Northern Italy. Environ Resource Econ 76, 611–634. https://doi.org/10.1007/s10640-020-00486-1

[56] World Bank (2002). Arab Republic of Egypt Cost Assessment of Environmental Degradation: Sector Note. Report No. 25175- EGT. http://documents.worldbank.org/curated/en/814181468751565459/pdf/multi0page.pdf

[57] WB (2013). The Arab Republic of Egypt For Better or for Worse: Air Pollution in Greater Cairo, A Sector Note. Report No. 73074-EG. World Bank Sustasinable Development Department, MENA Region. http://documents.worldbank.org/curated/en/972321468021568180/Egypt-For-better-or-for-worse-air-pollution-in-Greater-Cairo-sector-note

[58] Lowenthal, D.H., Gertler, A.W., Labib, M.W. (2014). Particulate Matter Source Apportionment in Cairo: Recent measurements and comparison with Previous Studies. International Journal of Science and Technology. 11:657-670.

[59] Egyptian Penal Code (1937). Law No. 58 of 1937. https://sherloc.unodc.org/cld/document/egy/1937/criminal_code_of_egypt_arabic.html, accessed: August 24, 2020.

[60] Mataghi, D., (2020). Ministry of Environment organizes the first workshop on mechanisms for integrating biodiversity into the urban planning sector [Arabic]. Al-Ahram Gate, Local news. Available at: http://gate.ahram.org.eg/News/2529445.aspx

[61] Arij, Al., (2020). Ministry of Environment: integrating biodiversity concepts into the urban planning sector [Arabic]. Akhbarak, Local news. Available at: https://akhbarak.net/news/2020/11/16/22697057/articles/40718748/

[62] HawaDawa, (2020) Understanding the impact of diesel phase-out on air quality using comprehensive air quality data coverage and AI-enabled data analysis. Marketing document. Website: https://hawadawa.com/

ANNEX 1: Hypothetical scenarios for discussion and illustrative purposes

Priority areas for LEZs?

Through satellite air quality imagery (see an illustrative example in Figure 23), it is shown that within the Egyptian inhabited areas, the Greater Cairo Metropolitan Area (GCMA) often exhibits highest emissions concentration values[e]. This suggests the need for further in-depth investigation (confirming annual average values of various pollutants, populations exposed in different cities, etc)[62]. However, through reviews of literature and past studies, expert evaluation, and expert interviews, it is found reasonable to identify GCMA as the priority region for air pollution countermeasures, both in terms of pollution and population exposure. In the meantime, public transport network coverage in GCMA is characterized by adequate and continually improving level of service, which is suitable to accommodate various vehicle access regulations.

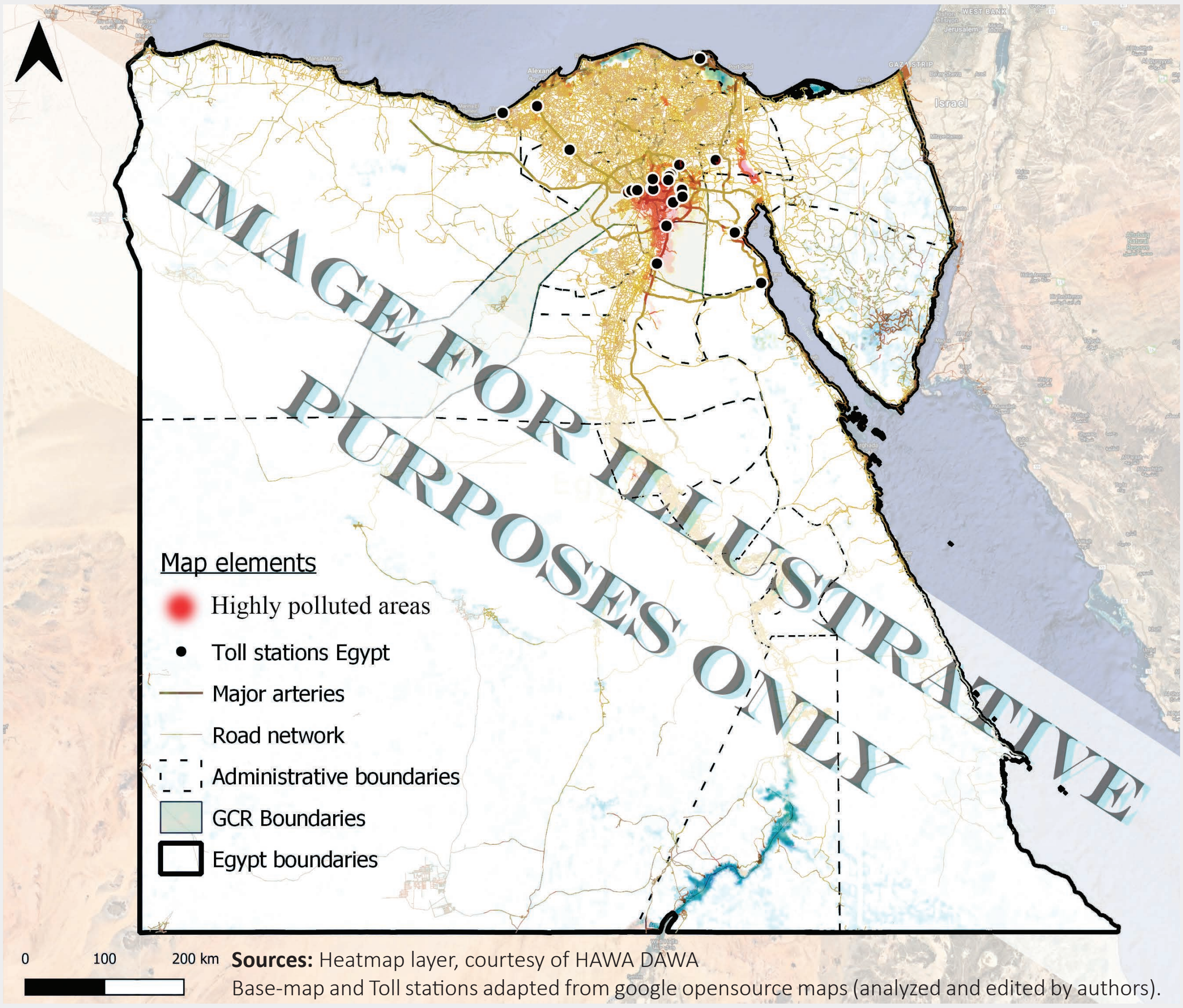


Figure 23: Egyptian road network, toll stations coverage and the intersection with air pollution mapping (illustrative example).

[e] Illustrations in this section are strictly for illustrative purposes only, showing examples of required studies before LEZs decision-making to facilitate discussions. The heatmap layer for air quality was courtesy of Hawa Dawa and edited by authors for simplification; satellite-based air quality data in this case was taken on September 14th 2019, as a snapshot of NO2 data, and not an annual average.

Based on that, and on the LEZs policy recommendations, for the initial LEZs phases, it is strongly advisable to start by the GCMR most polluted areas in its core as a first phase. These areas are well covered by public transport, and serviced with adequate road networks that guarantee a satisfactory provision of different options for users.

This phase can be the *marketing* stage of the policy (i.e. suggested for both the functional value and the marketing value), a winning situation that can provide realistic emission reduction measures within the first few years of the policy adoption. Later, after gradual public acceptance of the policy (and building competence of competent authorities), it can be expanded in area or also transferred to other cities starting with the most critically polluted ones.

Greater Cairo region LEZs?

The LEZs policy in the GCR can be implemented on 3 different phases, each with a certain level of restrictions that is suitable to the area infrastructure (See Figure 24). **The first scenario** shall include different sub-zones in historical and old Cairo neighborhoods, to decrease the inner-city pollution, protect valuable touristic locations and benefit from the existing public transportation network. This phase can act as a pilot LEZs practice, even though the sub-zones might have a minor impact, they will provide proper marketing for the policy application. The initial phase, however, can either be composed of sub-zones or be covered as one large LEZ, to guarantee the maximum emission reduction effect.

The second scenario can include the New Administrative Capital to connect with the latest public transport developments. It can start after the area is relatively inhabited to prevent future pollutants' spread and allow the area to sustain its natural air quality. **The third scenario** is suggested to include all the areas within the inner ring road boundaries (learning from the global practices, i.e. London and Rotterdam). The delay in this phase is to guarantee more social, economic, and political preparations for the restrictions. Finally, the LEZ can be simultaneously experimented and applied in neighboring cities, to prevent future pollution threats and to regulate all the new vehicle registrations.

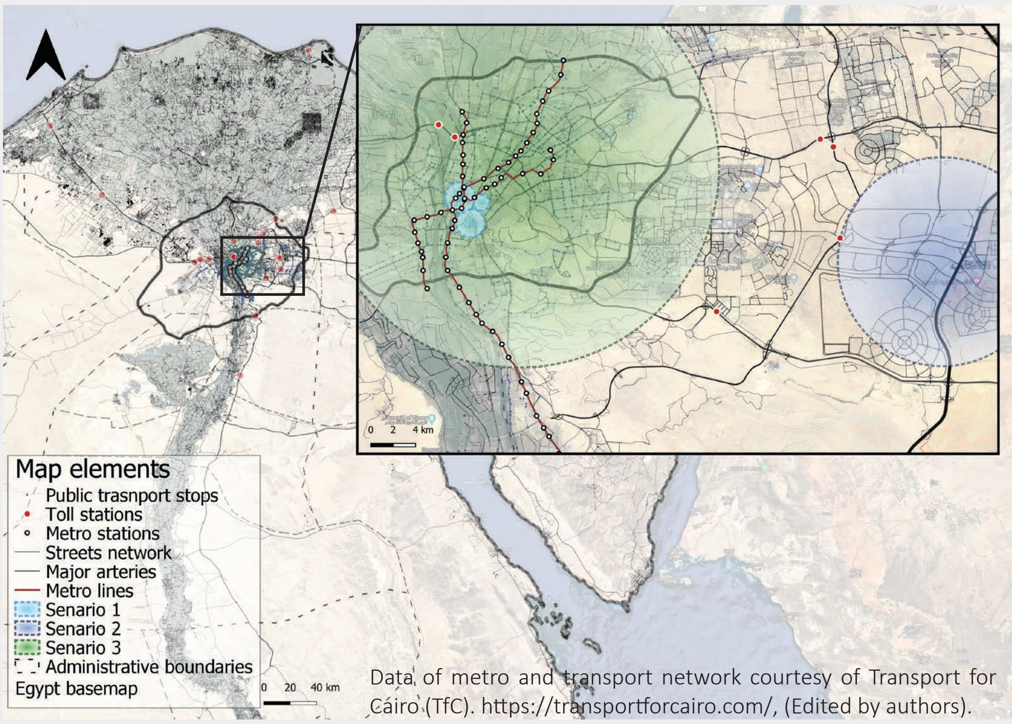
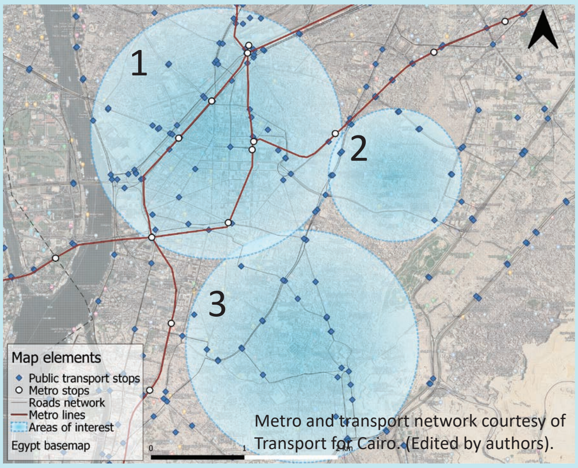


Figure 24: Transport network within the GCR and the LEZs proposed phases locations (transport and metro lines layer courtesy of Transport for Cairo online database, edited by authors).

Scenario-1: Historic and Khedival Cairo LEZ Sub-zones?

Proposed areas of interest



LEZ specifications

Areas to discuss (examples):

1. Khedival Cairo
2. Khan EL-Khalili area
3. Al-Khalifa district

... other parts of Historic and Khedival Cairo

Area: > 20 Km2

Examples of questions to discuss:

• How to preserve historic areas through vehicles access restrictions?

• Non-motorized and electric vehicles?

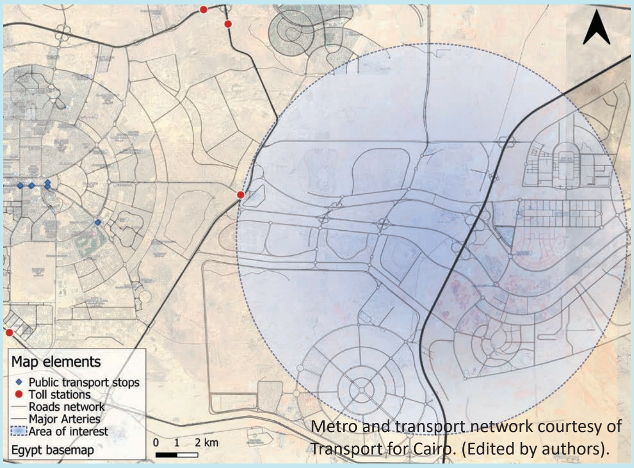
• What types of vehicles enter each zone?

• What are the alternative roads/transportation?

• What are the reduced impacts on buildings?

Scenario-2: New Administrative Capital flagship LEZ scheme?

Proposed areas of interest



LEZ specifications

Areas to discuss:

Phase-1 of new administrative capital.

Area: > 168 Km2

Examples of questions to discuss:

• What are the future transport connections for the area?

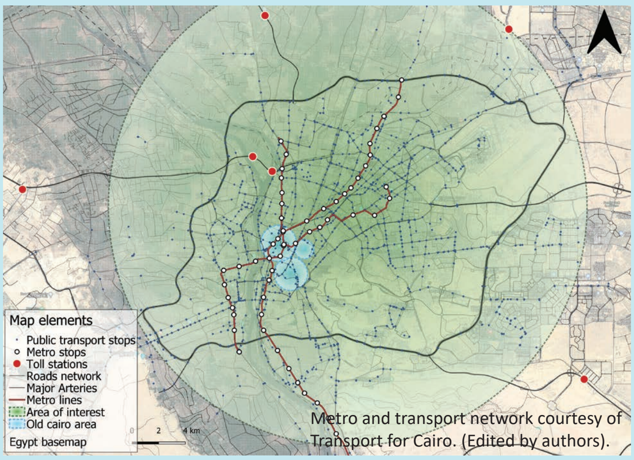
• What is the correct timing for the LEZ in the NAC?

• What is the expected outcome?

• What are the current alternatives provided in this area?

Scenario-3: Greater Cairo (Ring road) LEZ?

Proposed areas of interest



LEZ specifications

Areas to discuss:

Inner ring road boundaries

Area: > 445 Km2

Examples of questions to discuss:

• What is the socially acceptable level of restrictions?

• What is the expected outcome?

• How will it be different than the other Phase (scope wise)?

• What prerequisite enforcement needs to be taken care of before policy application?

• What is the estimated pollution reduction?

Other highly polluted areas?

To prevent the redirection of polluting vehicles to other areas of the road network outside the zone, or further into other cities, it is important to design and tailor LEZs for other cities of priority in terms of pollution exposure, especially that some of them include major industrial locations, while others are important touristic attractions. Cities can range from other large cities such as Alexandria, Fayoum, Aswan, Mansoura, to other smaller cities. Smaller cities may include coastal touristic cities such as Sharm El-Sheikh and Hurghada that can benefit from having a head-start in ensuring high sustainability standards.

Before the LEZ application and within the initial policy discussions the many questions must be answered for each city to initiate discussions among competent authorities. Examples of key questions are as follows:

- What is the proposed scope of restrictions?
- What already-existing capacities and capabilities (including institutional) can be mobilized/ leveraged to enable implementation?
- How many vehicles will be restricted? Is it worth the effort?
- What is the current and the expected pollution reduction?
- What is the largest source of emissions in the area?
- What are the existing alternatives for users?
- Are we able to provide low-sulfur diesel fuel?
- What are the potentials for higher standards of sustainable mobility (e.g. EV infrastructure, enjoyably walkable urban environment, etc)?
- How and where can the LEZ be monitored?
- How will the revenues be managed and reinvested into air pollution control and response measures?

Although other cities/zones can be considered for LEZ interventions at different points in time, nevertheless, in terms of the vision on a *national* scale, the fundamental approach must remain to pursue *evidence-based* prioritization of zones. This implies areas of highest vehicle traffic pollution and population exposure, i.e. to pursue what is 'correct' and not what is 'easy'.

Accordingly, even in the case of implementing flagship projects or interventions in small cities, the ultimate goal of the priority-areas must be set, and as such, a national strategy can be developed, with the vision for the phases of development and expected impact.