

Low Emission Zone: Lisbon's Experience

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Abstract—The problem of air quality in urban areas is an issue that has earned increasing attention of European Union and the Portuguese State throughout the last twenty years, culminating in the approval in 1996 of the European Air Quality Directive and its enforcement obligation in each European Country. The national Portuguese public body responsible for air quality management and monitoring elaborated Air Quality Plans and Programs and the respective execution programs for territories that don't comply with the defined air quality legal limits, which is the case of Lisbon Metropolitan Area. Only with the introduction of a legal process against the Portuguese state in 2011 it was politically possible to adopt clear restrictions to traffic emissions and implement a Low Emission Zone (LEZ) in Lisbon as it was proposed by the respective Air quality Plan for this territory. The two phases of implementation of Lisbon's LEZ already accomplished in 2013 a reduction of both 16% of Particulate Matter (PM10) concentration and a of 6% Nitrogen dioxide (NO₂), for the more polluted area of Lisbon (Av. Liberdade/Baixa Axis). It was also verified that the main impact of this LEZ was not the reduction of vehicle traffic circulation but the changing of vehicle fleet characteristics. This paper describes the implementation process of Lisbon's LEZ, the results obtained, the main problems that have been overcome and those that subsist, pointing out the conditions to develop the process until the accomplishment of the limits of pollutant concentrations imposed by law.

Index Terms—low emission zones, lisbon, air quality, air pollution.

I. AIR QUALITY AND POLLUTION IN LISBON

Pollution is characterized by the natural chemical change of atmosphere resulting from human activities (anthropic atmosphere pollution sources) and natural phenomena (thropic atmosphere pollution sources).

Pollutants impact on air quality varies according to its chemical composition, air concentration and weather conditions. Air quality is a determinant environmental component for public health, especially in urban environment. In fact pollutant effects on health are characterized by the emergence or aggravation of lung and cardiovascular diseases particularly in the most

fragile population like children, the elderly and the ones who suffer from respiratory diseases.

Particulate matter (PM10) and nitrogen dioxide (NO₂) are the pollutants that in most European urban areas require greater concern. The most common effects of Nitrogen Oxides (NO_x) on health condition as well as of particulate matter overexposure are correlated with respiratory diseases and lung tissue damage that can cause premature deaths. In city environment the origin of particulate matter is associated mainly with automobile traffic emissions, particularly diesel oil vehicles, but also with industrial and construction activities that can be aggravated by natural phenomena (like particulate transport from desert or forest fires).

A. Tackling Air Quality Problem in Lisbon Region

The problem of air quality in urban areas is an issue that has earned increasing attention of European Union and the Portuguese State throughout the last twenty years. The approval in 1996 of the European Air Quality Directive (Directive nr. 96/62/CE, from 27th September) fixed air quality objectives and parameters in order to prevent, reduce and avoid its harmful effects on public health.

The definition of air quality policy and management guidelines and the transposition for the national Portuguese law was made by the Decree-Law nr. 276/99 of 23rd July (altered by Decree-Law nr. 279/2007 from 6th August). This legal diploma defines that the competence of air quality management and monitoring is a responsibility of the Coordination and Regional Development Commissions (Comissões de Coordenação e Desenvolvimento Regional - CCDR), that have to take any necessary measures to ensure the respect of air quality legal limits in national territory. This legal diploma also stipulates that these entities (CCDR) should elaborate Air Quality Plans and Programs and the respective execution programs whenever some territories don't comply with the defined air quality legal limits.

Taking into account that the North and South Lisbon's Metropolitan Area and Setubal are agglomerations where repeatedly the air quality limit value and respective tolerance margin of PM10 (all mentioned agglomerations) and NO₂ (only in North Lisbon's Metropolitan Region) has been disrespected, the referred Commission of Lisbon (CCDR-LVT) developed the Plan and Program of Air

Quality Improvement for Lisbon Region (PPMQAr-LVT approved by Portaria n. 0715/2008, 6th August). This plan (PPMQAr-LVT) should be understood as the result of the air quality evaluation and diagnosis in all the air quality monitoring stations in these territories (Fig. 1). For the territories that surpassed repeatedly the legal air quality concentration limits the PPMQAr-LVT assessed and identified several policies and measures (P&M) to tackle this problem. With the approval of this strategic document the responsible institution (CCDR-LVT) formalized the execution of these measures through collaboration protocols with municipalities, which in the case of Lisbon was settled on the 16th September of 2008.

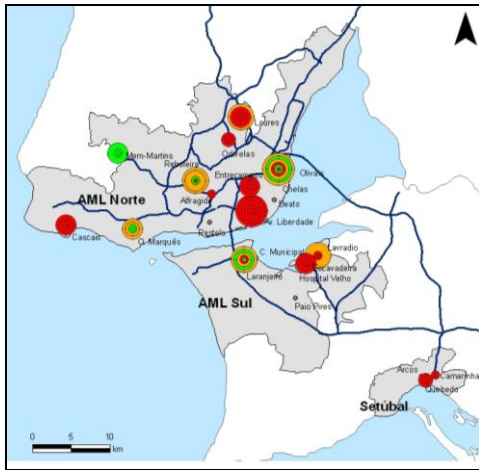


Figure 1. Daily and/or yearly registered concentration values of PM10 (2001-2006) (Source: FCT-UNL, 2008)

The Execution Program of the PPMQAr-LVT is approved in 2009 (through Despacho n.º 20763/2009, published in *Diário da República*, 2^a Série, n.º 180, 16th September of 2009) and represents the commitment to enforce the execution of all the measures proposed and which are of mandatory execution by the identified responsible institutions. Concretely the main goal of this Execution Program is to respect the PM10 limit values in “Lisbon Metropolitan Area” and “Setubal,” and to respect the NO₂ limit values plus the tolerance margin in the “North Lisbon Metropolitan Area”.

The creation of a Low Emission Zone in Lisbon was one of the measures proposed in the PPMQAr-LVT Plan in the field of management and traffic calming (measure M10). This measure was taken into account in the Execution Program and it was considered supra-municipal (Measure S2). In order to define the Low Emission Zone area, timing, format and specific vehicle restrictions it was created a sectorial workgroup taskforce with the contribution of several institutions (at national, regional and local levels)¹.

¹ Members of the sectorial LEZ working group: representatives of Environmental Secretary of State Cabinet (GSEA); Coordination and Regional Development Commission of Lisbon (CCDR-LVT); from University - Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa (FCT/UNL); National Road Safety Agency (ANSR); Municipality of Lisbon (CML) and National Institute of Mobility and Transports (IMTT).

II. IMPLEMENTATION PROCESS OF LISBON'S LOW EMISSION ZONE

A Low Emission Zone (LEZ) is a specific zone that only can be accessed by vehicles that respect certain pollutant emission standards (Ref. [1] Browne et al., 2007).



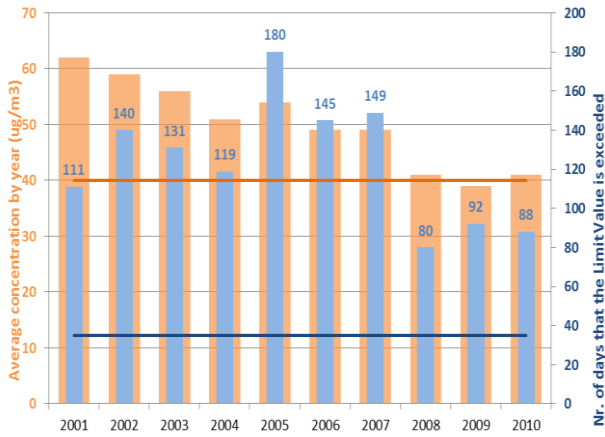
Figure 2. European Low Emission Zones (www.lowemissionzones.eu)

A Low Emission Zone can assume different formats, namely its application can depend: of the geographic area; time period that the circulation restriction applies; type of vehicles and different EURO emission standards that the vehicles must respect. In 2011 there were 225 LEZ in 11 European countries (Ref. [2]) and most of them were valid for 365 days/24hour per day and the restrictions were headed towards heavy vehicles (Fig. 2).

A. The Implementation of Lisbon's LEZ

Automobile traffic is the main source of air quality degradation in urban areas. In fact, since 2005 that Lisbon surpasses the European and national legal concentration limits for PM10 (particulate matter) and this occurs mainly in areas of greatest automobile traffic (Graphic 1). This given situation triggered a European Justice Court action against the Portuguese state in 2011 due to the disrespect of the European Air Quality Directive.

The proposed Lisbon LEZ would be implemented firstly in the area where there's a higher disrespect of PM10 and NO₂ limit levels since 2005: Av. Liberdade/Baixa. A thorough traffic study was made for this area of Lisbon city within the PPMQAr-LVT to characterize the origin and volume of pollutant emissions (Ref. [3]). One important finding of this study is related with the proportion of the Taxi fleet in the total emissions verified in Av. Liberdade. The high average age of the Taxi fleet has a strong impact on the total particulate matter emissions when comparing with the total light vehicle traffic in this axis (Ref. [3]). Concretely the Taxi Fleet corresponds to 17% of the total light vehicles in circulation in this axis, but their pollutant emissions account with one third of the total emissions of this vehicle category.



Graphic 1- Average yearly concentration of PM10 and number of days that the limit value was exceeded at the Air quality Monitoring Station of Av. Liberdade

The approval of the 1st phase of Lisbon’s LEZ in the 18th of May 2011 (Deliberation nr. 247/CM/11, published in the 3rd supplement of the Boletim Municipal n.º900, from 19th May 2011) and its implementation on the 4th of July 2011, were a first step to the beginning of an air quality improvement process in the city of Lisbon.

Despite the requirements of the PPMQAR-LVT Execution Plan and the impositions of the European Air Quality Directive, Lisbon Municipality opted for less exigent restrictions than what was established in the initial implementation calendar (discussed with all the stakeholders). Instead of implement Lisbon LEZ throughout the entire city perimeter in January of 2011 it was implemented in July 2011 and only for the most critical area of Lisbon in terms of air quality.

The first phase of Lisbon’s LEZ is characterized by the restriction of light and heavy vehicle traffic that don’t meet the EURO 1 Emission Standard (vehicles built before July 1992), during the weekdays between 8h and 20h in the Av. Liberdade and Baixa Axis (total area of 0,6 km², approximately 1% of Lisbon City Area). It was also authorized crossings in this restricted area to connect the hills at Lisbon downtown (Fig. 3).



Figure 3. Area of the 1st phase of Lisbon’s Low Emission Zone

For this phase several exceptions were admitted according to the nature of activity or the ownership of the

vehicles; law exceptions for emergency vehicles and others; historical licensed vehicles; residents and commerce vehicles with special parking permit for this area (Zone 5 – Av. Liberdade, Zone 12 – Chiado and Zone 13 – Baixa). Public transport vehicles (light and heavy vehicles) were also exempted in this phase, taking into account a special request from the National Institute of Transports and Mobility. This exemption would only take place until the implementation of the second phase, allowing with this the time needed to implement a technical protocol for the retrofit of old vehicles.

The delimitation of the Low Emission Zone was made with vertical traffic signs. According to the National Authority of Road Safety the “Forbidden Traffic Circulation Zone” sign was the most appropriated given the National Traffic law (RST – approved by the DR nr. 22-A/98 from 1st October and with the changes by the DR nr. 41/2002 from 20th August). Concretely this traffic sign – “Forbidden Traffic Circulation Zone” (G5a – Table XXVIII) - means that all the vehicles that match the unauthorized criteria cannot enter this zone.

This traffic sign was complemented with additional panels (model 19 – Table XXXV) where the unauthorized criterion is specified as well as the period of time of the application of this restriction (Fig. 4).

As there is no specific sign in Portugal to identify a Low Emission Zone –as it happens in other European countries - this artificial solution was the only one that Lisbon Municipality could use to restrict the circulation according to air quality parameters. The problem of this artificial solution was that the penalty for disrespecting the restriction is very low. In other way, the exemptions considered makes that the restrictions only affected 10% of the total car traffic circulating on this axis.



Figure 4. “Forbidden Traffic Circulation Zone” used in the 1st phase of Lisbon’s Low Emission Zone

The enforcement applied in this first phase was made on a random basis by the police authorities. Several vehicle characteristics information was verified like the license plate number, the vehicle documents, parking permits, etc. The potential fines would be processed by the National Authority for Road Safety after receiving fining details from police authorities.

The approval of the second phase of the Low Emission Zone in Lisbon occurs on the 29th February 2012

(Deliberation nr. 105/CM/12, published in the 3rd supplement of the Boletim Municipal n.º 941, from 1st March 2012) and is effective in the city on the 1st of April 2012. In this phase the environmental constraints were aggravated in the Av. Liberdade/Baixa Axis and the new Low Emission Zone area was widened to one third of the total area of Lisbon (26 km²).

The second phase of Lisbon's LEZ is characterized by the restriction during the weekdays between 7h and 21h of light and heavy vehicle traffic that don't meet the EURO 2 Emission Standard (light vehicles built before January 1996 and heavy vehicles built before October 1996) in the Av. Liberdade and Baixa Axis (Zone 1) and by circulation restriction of vehicles that don't meet the EURO 1 Emission Standard in the rest of Lisbon's LEZ area (Zone 2) (Fig. 5).

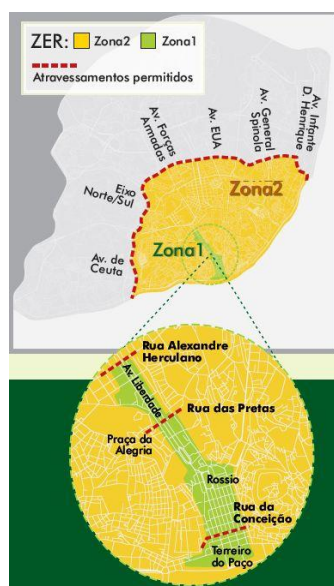


Figure 5. Area of the 2nd Phase of Lisbon LEZ (Zone 1 and 2)

The exemptions globally remain the same as the ones from the 1st phase, although collective transport vehicles are no longer exempted. Initially all vehicles affected to public transport (collective transport and taxis) wouldn't be exempted in the second phase, but taken into account the late published decision² of the National Institute of Transports and Mobility on how to homologate "retrofit" technologies and the feeling of uncertainty as to the possibility of adapting 20 year old vehicles with "retrofit" technologies, the municipality of Lisbon approved in the 11th of April 2012 a deliberation that extended this exception until January 2013 (Deliberation nr. 170/CM/12, published in the 5th supplement of Boletim Municipal nr. 947, 12th April 2012).

B. Communication

The communication slogan for the Low Emission Zone in Lisbon was "More Lisbon: less pollution – more oxygen – breath better – live more Lisbon" ("*Mais Lisboa: menos poluição – mais oxigénio – respirar melhor – viver mais Lisboa*") and its main message was

² Deliberation nr. 525/2012, published in Diário da República – 2.ª Série – n.º 70, 9th April 2012

to transmit a positive message associated to the improvement of air quality in the city instead of the negative idea of restricted vehicle circulation.

The marketing and information campaign used the traditional municipality means of communication, such as: website; Cultural monthly Lisbon Magazine; open-air public TV circuit; MUPI city circuit and specific flyers (Fig. 6) (distributed in Lisbon Districts, public facilities and police stations).

In what concerns institutional communication several information and discussion sessions were made with the national and municipal police authorities. In the field the municipal police authority collaborated with the municipality in this awareness campaign and specifically designated effectives for this task in the first month of the LEZ implementation process in order to inform the citizens.



Figure 6. 2nd phase communication flyer

C. Next Steps

Currently it is being studied the implementation of the 3rd phase of Lisbon's LEZ. Geographically there won't be changes and the municipality will maintain 2 different zones (Zone 1 and Zone 2) although with higher environmental restrictions: upgrading Zone 1 to EURO III and Zone 2 to EURO II, with no exception to the taxi fleet. The implementation of this 3rd phase is however dependent on the type of monitoring that will be implemented in the City of Lisbon. The automatic electronic plate number reading system associated with the database of the National Institute for Mobility and Transport information containing the EURO standards of each vehicle is perceived as the most effective solution, although not necessarily the most economical.

III. RESULTS

According to Decree-Law n.º102/2010, the hourly limit value for NO₂ (200 µg/m³) only can be surpassed 18 times in a year. For particulate matter (PM10) the daily limit value (5µg/m³) can only be exceeded 35 times in a year.

The first monitoring report (elaborated by Faculdade de Ciência e Tecnologia from Universidade Nova, FCT-UNL) (Ref. [4]) pointed out that the exceeded limits of NO₂ and PM10 concentration occurred mainly in the streets where are located the traffic air quality measuring stations. In fact the Air quality station of Av. da Liberdade is the station where the worst values are

registered for NO₂ and PM10 concentrations and also where it is registered the higher overcome of the limit values by year.

If the implementation of the first phase didn't except the public transport (particularly the taxi fleet), PM10 reductions could be of 13% and NO₂ reductions could be of 10% in Zone 1, for 5% restrictions of vehicle circulation according to modelled calculations of FCT-UNL.

Only in 2013 with the third monitoring report from FCT-UNL (Ref. [5]) it was possible to assess the results of the Lisbon's LEZ implementation strategy, comparing 2011 with 2012 data in what concerns the type of vehicles in circulation and air quality parameters.

Actually comparing average daily traffic in 2011 and 2012 there was a slight reduction both inside LEZ (3% reduction) and outside LEZ area (4% reduction) (Ref. [6]). FCT-UNL based on this reality concludes that the implementation of the Low Emission Zone in Lisbon didn't have a strong impact on the decrease of vehicle traffic circulation and points out that this reduction may be correlated with economic crisis and the increase of fuel prices among others because the reduction percentage of traffic circulation both inside LEZ and outside was very similar (Ref. [6]). This information is interesting because it contradicted the negative opinion of some sectors in the city of Lisbon that predicted a great loss of vehicle traffic circulation and the decrease of economic activity inside LEZ perimeter.

But if vehicle traffic circulation didn't decrease and as it is considered the main source of pollutant emissions, what was the interest of LEZ implementation in the city? The answer to this question relies on the fact that the main impact of a LEZ it's not the reduction of vehicle traffic circulation but the changing of vehicle fleet characteristics. This premise of fleet renovation was verified by a field "fleet characterization survey" where the main findings indicated that there was an increase of EURO4 and EURO5 vehicles in circulation along with a reduction of Pr €EURO1 and EURO1 vehicles.

In what concerns air quality and despite the fact that 2012 was a year that registered less precipitation and colder temperatures (favourable conditions to pollutants accumulation), the registered values of 2012 average year concentration of PM10 reduced by 16% (Fig. 7) and NO₂ reduced by 6% (Ref. [7]) in Av.Liberdade/Baixa Axis.

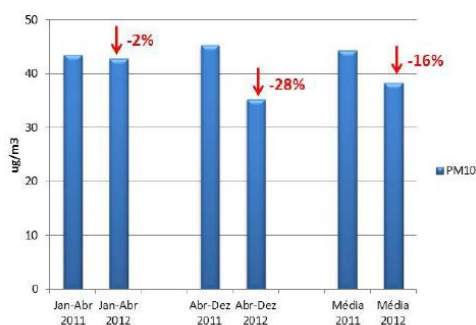


Figure 7. Comparison of 2011 and 2012 PM10 concentration values registered in Av.Liberdade/Baixa Axis (January-April; April-December; Average 2011 and 2012)

In terms of the number of days that the limit values of PM10 were exceeded in Av.Liberdade Air Quality Station, 2012 was a better year than 2001 although its 72 exceedances (2012) are still above the legal limit. The exceedances of the limit value of PM10 concentration admitted by law are in most cases less than 10% in 2012 which is a very positive evolution when comparing with the last years. This fact indicates a very good prognosis to accomplish the legal allowed PM10 concentration limit values when the LEZ applies Taxi fleet also, concretely the registered values for the first semester of 2013 indicated that this could be the year that the limit values would be respected. For NO₂, 2012 was the year that the registered average concentration was lower since 2002 (Ref. [5]).

Within the LEZ implementation process there was a renewal and retrofitting of vehicles affected to non-regular public transport service (touristic tours operators and occasional transport operators) when the exception for these types of vehicles was repealed. After negotiating a term of one year so that they could adapt their vehicles or renew their fleet, it was possible to ensure that by mid-2012 heavy vehicles that didn't respect Euro 3 ceased to circulate.

Unfortunately this fleet renewal didn't happen in the Taxi sector. The causes for this can be attributed to the lack of financial or fiscal support, and missing technical procedures that were exclusively governmental responsibility. Despite this absence of cooperation the Municipality of Lisbon in cooperation with Taxi professional associations (ANTRAL and Portuguese taxi Federation, FPT) created a fleet renewal program. This program consisted in the attribution of a financial incentive of 3.000€ to support the purchase of 20 electric vehicles for taxi economic activity and the destruction of the correspondent old vehicles. Being aware that this would not solve the problem per se the municipality of Lisbon considered that this program could be a first step to create the awareness needed in this sector for the demands of air quality legislation and also could be very positive to foster a fruitful cooperation between these stakeholders.

IV. CONCLUSIONS

The main goal behind the implementation of Lisbon's LEZ was the need to reduce the pollutant concentrations (PM10 and NO₂) where the worst values were registered and for several years surpassed the legal limit. Facing a legal action from the European Court of Justice against the Portuguese State by the infringement of Air Quality concentration limits contributed to create the political conditions to act on this matter and to comply with what was proposed in the Execution Program of PPMQAr-LVT plan.

Lisbon strategy was based in two fundamental aspects. First, facing with realism a LEZ process of implementation in Lisbon following a "small steps" policy that would not turn them reversible and that would warranty a broader political support from all stakeholders. Secondly and as a consequence of a "small steps" policy

strategy, the municipality had to reformulate the initial design and characteristics of Lisbon's LEZ (Phases, exceptions and geographic limits). For the first phase not only LEZ area was smaller but unquestionable, but also it was considered a high number of exceptions (residents, shop owners, collective transport operators including taxis) and the respect for the lowest EURO standard existent (EURO1).

The main goal of this first phase was not focused on a significant reduction of PM10 and NOx concentrations but on the break of the inertia in this subject and starting to materialize concrete measures to improve air quality in the city.

Somehow the softness with which the general public faced restrictions (the reduced perimeter, the numerous exceptions and belting them only to the Euro 1 standard) was the price to pay so that the municipality could implement the Low Emission Zone. Reality showed that this strategy was the most adequate for the context in time, although considered by some minimalist and fearful.

However the Municipality after the recognition of the first results obtained (mainly the ones related with fleet characteristics that circulated inside the LEZ) would have to move forward decisively in relation to the suppression of some of the exceptions considered, enlarging LEZ perimeter and circulation restrictions in compliance with higher Euro standards. If considered only the last two aspects, with the enlargement of LEZ perimeter to the limit of the most congested part of the city (2nd phase) and the establishment of EURO2 standard as the environmental standard restriction (Zone1), it was possible to accomplish what was defined since 2008. Although if we consider LEZ exemptions, Lisbon Municipality was forced to extend them because of the lack of governmental support in what concerns fiscal and financial incentives for taxi fleet renewal, establishment of technical "retrofit" processes, the prohibition of taxi license renewal for vehicles that don't respect LEZ Emission standards and also their importation.

Indeed, the exception of taxis considered in the first and second phase of LEZ implementation - when they are responsible for one third of the emissions of cars on Av. da Liberdade - did not contribute positively to the achievement of expected results of this measure. From a total of 3445 Taxis operating in Lisbon about 32% doesn't respect EURO2 Emission Standards (275 Pre-Euro and 802 Euro1). Despite the alleged unawareness of LEZ measure in this sector, it is a fact that the Professional Taxi Associations (ANTRAL and FPT) were consulted and participated in the framework of the Working Group established to implement Lisbon's LEZ in 2008 and however they didn't renew their fleet.

The municipality of Lisbon tried several forms of negotiation in order to implement different solutions for fleet renewal of the taxi sector, but could not get the necessary support from the Government to find a realistic solution to solve this problem.

Another problem that delayed the transition to the third phase of LEZ in June 2013 - later postponed to January 2014, without also been finalized on that date - had to do

with the effectiveness of the enforcement foreseen for the new LEZ perimeter considered in the second phase of ZER.

Indeed, despite the good collaboration with the traffic police of PSP Lisbon, the scarcity of resources didn't make it possible to obtain a satisfactory level of effectiveness of the available enforcement. To enforce the 26 km² of LEZ area it would be necessary to have an automatic system that depended of previous authorization from the National Data Protection Commission (CNPD) to use traffic cameras to detect plate numbers as there actually exists for automatic tolls in highways. This clearance decision was only given by CNPD in the end of the last political mandate (October 2013), which prevented the necessary acquisition of the cameras and the assembly of the automatic enforcement system. Without this system it doesn't make any sense to go forward with higher demanding restrictions since the effectiveness of its enforcement is very low.

Finally, depending on the agreements that will be establish with the National Transport and Mobility Institute, it is expected that in the near future, the enforcement can be performed through direct observation of the colour of the "vehicle inspection card", which will have different tones depending on 'Euro standard 'that the vehicle complies.

The repeated situation of disrespect for the limit value of pollutants due to road traffic in Lisbon - where the axis of Avenida da Liberdade / Low presented the worst results (80 exceedances per year, when only 35 are allowed) - led in 2011 the European Commission to start a legal action against the Portuguese State in the European Court of Justice. Even with 30% reduction of traffic verified in this area of Lisbon City after the new vehicle circulation scheme in Baixa/Cais do Sodré air quality improvements (from 130 exceedance days to 75) weren't sufficient to meet the standards negotiated in 2008. On the 15th November the Portuguese state was condemned for the exceedance of pollutant limit values between 2005 and 2007 (Process C34/11) in several areas of the country, especially in Lisbon city.

Nowadays we know that only completing the implementation process of Lisbon's LEZ as it was defined and approved by the municipality in 2012, it will be possible to respect the legal limit values for PM10 and NOx. The main problems that caused the suspension of this process in mid-2013 are outdated now and it's only up to the municipality of Lisbon to concretize the solutions that were found. However the taxi problem subsists - actually the major responsible for pollutant emissions - and it would be only possible to solve it with a tighter cooperation between the Government and the Municipality. Perhaps the biggest problem to solve in this current context.

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