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Air quality improvements following implementation of Lisbon's Low Emission Zone

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HIGHLIGHTS

- PM_{10} and NO_2 levels in Lisbon have been exceeding the legal limit values since 2001.
- An action plan was developed with a set of measures including a LEZ in Lisbon.
- We assessed air quality and traffic data before and after LEZ full implementation.
- Results show positive evolution between 2011 (before LEZ) and 2013 (after LEZ).
- Stricter restrictions and enforcement are fundamental in future stages of the LEZ.

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ABSTRACT

Air pollution levels within Lisbon city limits have been exceeding the limit values established in European Union and national legislation since 2001, with the most problematic cases related to the levels of fine particles (PM_{10}) and nitrogen dioxide (NO_2), mainly originated by road traffic. With the objective of answering this public health issue, an Air Quality Action Plan was developed in 2006 and the respective Enforcement Plan was published in 2009. From the overall strategy, one of the major measures presented in this strategy was the creation of a Low Emission Zone (LEZ) in Lisbon, which has been operating since July 2011. Implemented at different stages it has progressively expanded its area, including more vehicle types and adopting more stringent requirements in terms of minimum emission standards (currently LEZ phase 2 with EURO 2 in the city center – zone 1 and EURO 1 in the rest of the LEZ area – zone 2). At the same time the road axis comprised of Marquês de Pombal square and Avenida da Liberdade was subjected to profound changes in its traffic circulation model, reducing road traffic volumes.

The analysis of the air quality data before and after the LEZ phase 2 has shown positive evolution when comparing the period between 2011 (before measures) and 2013 (after measures). In 2013, there was a reduction in PM_{10} annual average concentration of 23% and NO_2 annual average concentrations of 12%, compared with the year 2011. Although PM_{10} reductions were more significant inside the LEZ area, the same was not valid for NO_2, suggesting that the implementation of these measures was not as effective in reducing NO_2 levels as shown by results in other cities like Berlin and London. The results from road traffic characterization indicate a relevant effect on fleet renewal with an overall decrease in the relative weight of pre-EURO 2 vehicles in 2012/2013, compared with data from 2011. An important increase in the share of EURO 4 and EURO 5 vehicles was also observed. Our conclusions show that the level of ambition is relevant for the observed effects. Therefore, stricter restriction standards should be enforced in the future stages of the Lisbon LEZ in conjunction with a higher effort and investment on LEZ enforcement.

1. Introduction

Air pollution levels in several locations in the Lisbon and Tagus Valley region, particularly within Lisbon city limits, have been exceeding the limit values established in European Union and

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national legislation for certain pollutants since 2001. The most problematic cases are related with levels of fine particles (PM_{10}) and nitrogen dioxide (NO_2).

The highest pollution levels in urban centers have road traffic as its main cause, particularly due to heavy commuting. In the city center, the levels of air pollution threaten public health, surpassing some of the World Health Organization (WHO) thresholds – guideline levels for PM_{10} are 20 μg/m^3 as annual mean, 50 μg/m^3 24-h average; guideline levels for NO_2 are 40 μg/m^3 annual mean, 200 μg/m^3 hourly average (WHO, 2006). An important and extensive review work on this topic was made by Pope and Dockery (2006) summarizing and discussing studies on short and long term PM impact on mortality from respiratory and cardiovascular diseases due to air pollutant exposure.

According to EU and Portuguese legislation, action has to be taken to bring exposure concentrations to acceptable levels within a reasonable timetable. In this context, an Air Quality Action Plan has to be deployed ensuring the reduction of the exposure related risks. Air quality action plans have a strong emphasis on traffic regulation and involve policies such as the stimulation of public transportation usage, ring road utilization, traffic flow improvements, speed limit reduction, and the implementation of Low Emission Zones (LEZ) (Panteliadis et al., 2014).

The Greater Lisbon Metropolitan Region also applied this approach, thus in 2006, the Air Quality Action Plan for Lisbon and Tagus Valley (AQAP-LTV) was published (CCDR-LVT and DCEA-FCT/UNL, 2006). Its main objective was to ensure compliance with legal limit values set out in Decree-Law no. 102/2010 of September 23, 2010 (which transposes to national legislation Directive 2008/50/EC of the European Parliament and of the Council of May 21, 2008, on ambient air quality and cleaner air for Europe. This Directive results from the revision and merge of the previous Framework – Directive 1996/62/EC of September 27, and Daughter Directives – 1999/30/EC of April 22, 2000/69/EC of November 16, 2002/3/EC of February 12 and 2004/107/EC of 15 December 2004).

From all possible policies and measures (P&M) that were identified in the AQAP-LTV, a smaller group was selected containing the P&M considered most likely to be implemented, taking into account political, financial and technical constraints, as well as their cost-effectiveness. In 2009, the Air Quality Action Plan's Enforcement Program (AQAPEP -LTV) was published containing this selected group of P&M (CCDR-LVT and DCEA-FCT/UNL, 2009). From the overall strategy, one of the major P&M presented in AQAPEP -LTV was the creation of a Low Emission Zone (LEZ) in Lisbon.

Low Emission Zones are one of a number of strategies that have been employed by governments to try to reduce, or limit, the emissions of air pollutants from road traffic within a specific spatial area (Ellison et al., 2013), hence it is a specific zone that can only be accessed by vehicles that respect certain pollutant emission standards (Browne et al., 2007). More than 200 cities and towns in 10 countries around Europe have already implemented a LEZ, namely London, Berlin, Amsterdam and Stockholm, or are preparing its implementation like Budapest, Trondheim and Oslo (Sadler Consultants & EU, 2014). A LEZ can diverge in terms of geographic scope (some extend to the full city, others enclose restricted areas only), period of operation (some operate 24 h per day, 365 days per year, others only on weekdays only or during working hours), type of vehicles affected (some affect all types, others only heavy duty vehicles), and level of strictness (depending on the minimum EURO standard required).

Evaluating the success of a LEZ implementation may become a very complex task since there is a wide multiplicity of indicators that could be looked at. At the end, the LEZ effectiveness can be assessed evaluating the expected emission reductions obtained for air pollutants, like PM_{10} and NO_2, but other results might provide an inconclusive picture regarding the benefits of LEZ. Moreover, sometimes results are not as successful and clear as originally thought. As an example, studies in Amsterdam show that with the exception of one urban street where traffic flows were drastically reduced, no measurable benefit was obtained so far (Boogard et al., 2012). Also, there were significant decreases in traffic-related air pollution concentrations in the vicinity of a roadside monitoring station after the implementation of the LEZ in Amsterdam (Panteliadis et al., 2014). In Munich, there has been a positive effect of its LEZ implementation on the reduction of particulate organic compounds (POC) concentrations, but not significantly due to the variation of its sources (Qadir et al., 2013). In Berlin, a study shows that the turnover of the vehicle fleet towards cleaner vehicles has speeded up considerably only because of the LEZ. The same study also posts that the LEZ is the most effective single measure in Berlin, provided that ambitious emission criteria are required within a reasonably short time scale, not watered down by extensive granting of exemptions for residents. However, there was a much larger reduction in PM_{10} emissions than in NO_2 (Lutz and Rauterberg-Wulff, 2010). The evaluation of the London LEZ from Ellison et al. (2013) suggests that the rate of fleet turnover for affected vehicle classes increased substantially when the LEZ was first introduced before returning to the national average in subsequent years. Also, ambient air quality measurements show a higher decrease in PM_{10} concentrations within the LEZ, when compared with areas just outside the zone. However, no discernible differences are found for NO_X concentrations (Ellison et al., 2013). Other studies show that reductions in airborne particle number concentration in London are primarily due to the change in Sulphur fuel content, and not because of the LEZ implementation (Jones et al, 2012). A recent meta-analysis from Holman et al. (2015) indicate that in German cities (where both passenger cars and HDV are restricted) there was a reduction in PM_{10} and NO_2 annual mean concentrations of up to 7% and 4% respectively due to the LEZ implementation. It was also observed by these authors that in other European cities (Denmark, UK, Netherlands and Italy) the effect of the LEZ in ambient air quality is less clear, due to the influence of several confounding factors like meteorology and the economic crisis. However, these authors did find limited evidence that LEZs may result in larger reductions in the concentration of carbonaceous particles.

Lisbon's LEZ has been implemented at different stages, progressively expanding its area, including more vehicle types (for example, by repealing the exemption for public transport buses), and adopting more stringent requirements in terms of minimum emission standards required to access the LEZ (Ferreira et al., 2012). Fig. 1 depicts the geographical scope of the LEZ and the different zones associated with the sequential implementation areas. The 1st phase began on July 4th, 2011 at the Marquês of Pombal/Terreiro do Paço axis (zone 1). In this area, circulation of pre-EURO vehicles (prior to 1992) was banned on weekdays between 8:00 h and 20:00 h. On April 1st 2012 the 2nd phase began, encompassing a much broader area of about one-third of the whole city of Lisbon (zone 2) where circulation of pre-EURO vehicles was banned. In parallel, in zone 1 the minimum standard was increased to EURO 2. The operative hours of the LEZ were also extended (weekdays from 7:00 h to 21:00 h). The restrictions for circulation allow several exceptions according to the nature of activity or vehicles ownership: emergency and military vehicles, historical licensed vehicles, city residents (for zone 2), residents of city center/commerce vehicles with special parking permit (for zone 1), and taxis.

At around the same time of the LEZ implementation (on September 16th 2012), the road axis comprised of Marquês de Pombal square and Avenida da Liberdade was subjected to profound changes in its traffic circulation model, with the purpose of