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Review of European Low Emission Zone Policy

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Low Emission Zone policy (LEZ) is considered one of the most reliable and efficient Travel Demand Management (TDM) measures. LEZ concept first appeared in Europe in the form of Access Restriction (AR) measure (e.g. Rome ZTL). This article discusses the European LEZ scheme's advantages and flaws. The goal is, first analysing the policy's perception, impacts, and instruments. Second, evaluating this policy's performance and efficiency in achieving the goal of the European Union (EU), which is eliminating diesel vehicles and encouraging eco-friendly and green mobility. Generally, European cities are ahead of others in the term of the implementation of environmental policies, but not all cities could be considered succeeded in implementing LEZ schemes.

1. Introduction

Transportation is the main contributor to air pollution. Traffic emissions are rapidly increasing compared to other sectors (Fan et al., 2018). Hence, both researchers and governments were interested in traffic emission reduction policies and measures. The pollution reduction measures in Europe appeared in the form of an Access Restriction (AR) rules, especially in the central areas (CBD), for instance, Rome's Limited Traffic Zone (LTZ) policy in 1989. Generally, the AR policy aims to protect damaged zones and enhance their attractiveness, through the restriction of polluting vehicles, usually diesel vehicles, either fully or partially (Ungemah and Dusza, 2008). Although diesel is a powerful energy source, it is responsible for high traffic emission and considered the dirtiest engine fuel (Mohammad Rozali et al., 2015). This policy is, often, accompanied by other strategies like promoting walking, cycling and public transit in one hand, and parking and congestion management, on the other hand. However, despite the wide public acceptance, LEZ policy could suffer from strong opposition, especially within commercial areas, where it is viewed as obstacles. Therefore, the policy should be carefully planned, while considering the economic and social characteristics of the studied zone (Meyer, 1999). After the recognition and popularity of AR, Sweden has initiated a policy improvement to get stronger environmental impacts, thus Sweden was the first to emphasize on the environmental aspect with its 'environmental zone' policy deployed in 1996. Following Sweden's initiative, the European community improved and standardized the policy, under the title of the LEZ scheme. Many European countries have adopted this policy, like Germany, the Netherlands, Italy, France, and the United Kingdom (Boogaard, 2012). Despite the scarcity of scientific articles on the European LEZ comparison and evaluation, many reports from governments and international community evaluated the policy, by focusing on specific city or country, however this paper gives a quick summary on noticeable cities, and provides solid reference to build a strong model of the policy. This paper reviews and evaluates European LEZ policies in Milan, Rome, Paris, and London, and gives a quick summary and highlights the differences and similarities within the mentioned cities. It provides a critical review and recommendation for possible improvement.

2. Literature review

Sweden is considered the first country to implement LEZ policy, with its current conventional meaning, in 1996, through the implementation of environmental zones, as well as the ban of old polluting vehicles emitting

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PM emissions. In 2002, the policy added the restrictions of NO_x emissions, which led to the establishment of the national LEZ scheme in 2006 (Sävbark et al., 2006). The second country to adopt it was France through the Mont Blanc Tunnel between France and Italy, but recently, Germany and Italy are the most enthusiastic toward the policy. Settey et al. (2019) believe that the implementation of LEZ, not only reduce emissions, but also could indirectly help improve road safety.

The LEZ policy gained good public support; because it boosts the environment while providing several mobility alternatives to citizens. Usually, within LEZ areas, vehicles with a higher emission level should be banned from entering, nevertheless, sometimes, they just have to pay a higher toll (OECD, 2010). Therefore, the European Commission has categorized vehicles according to their level of emission, and fuel type. European emission standards apply to all circulating vehicles and categorize them according to their types (two/three-wheeled), function (passenger cars, commercial cars, freight, etc.), and fuel (gasoline or diesel). Hence, each vehicle has different emission limits and test procedures.

All European countries have adopted the same vehicles' categorization. Furthermore, about 200 cities in Europe that have implemented the LEZ policy (Sadler, 2014). However, LEZ requirements are not fully harmonized across Europe. Rather, each country adapts the requirements to its specific regulations, while respecting the EU's big instructions. Unfortunately, the EU did not consider the differences between European countries, especially the east and west, in terms of financial and technological abilities and resources.

Many European cities are still exposed to poor air quality. The 'European Environmental Agency' stated that 21-33% of the urban population lives in areas where PM_{10} exceeds European standards (EEA, 2014). Furthermore, even though the European Union air quality directive demanded to achieve PM_{10} and NO_2 limit value by 2005 and 2010, with a possible delay until 2010 and 2015; the most European countries could not achieve the goal, and asked for time extension for one or both particle (Holman et al., 2015). Diesel vehicles are the main source of traffic emissions. And as the LEZ policy aims to reduce emissions of PM (PM_{10} and PM_2.5) and nitrogen oxides (NOx); diesel vehicles should be more restricted, with a bigger goal of a complete ban (T&E, 2018). Less than 10% of new Euro 6 diesel vehicles satisfy EU's emission limits, and many cities exceed the EU limit values for zonqa10 and/or NO_2 (T&E, 2018). However, according to the website 'dieselnet.com', LEZ regulations include: first banning high emission vehicles; which are below the permitted European standard level, second, permitting retrofitting options for some vehicles, such as a diesel particulate filter, and finally, implementing charging schemes through pricing regulations.

Therefore, regulations should be strengthened especially for diesel vehicles, either they abide by the rules or be banned from circulating. The T&E (2018) report revealed that the Euro 6 exemption is the real reason behind the failure of achieving the targeted emission values and banning diesel vehicles form European roads. The report criticised the exemption rule and asked to be removed from LEZ policy. However, the report did not provide feasible alternatives to policy-makers and ignored the issues that all governments face when dealing with big private companies regarding diesel vehicles.

3. Low Emission Zone's policy in Milan, Rome, Paris, and London

In response to the increase in congestion and pollution, the European commission aim reducing cars on the European roads, as well as banning high polluting vehicles. For this purpose, European Commission has categorized vehicles according to their level of emission. However, European policy suffers from the weaknesses of the exemption for Euro 6 vehicles (T&E, 2018).

In fact, less than 10% of new Euro 6 diesels on sale today meet the EU emission limits. While 90% still exceed the nitrogen oxides limit by 4 to 5 times and some models up to 10 times, notably from carmakers such as Renault, Fiat and Opel. These diesels should either be upgraded to comply with the limits or not allowed in cities - only the vehicles that meet the pollution standards on the road should be exempted from bans (T&E, 2018). But, until now the central could do nothing in this regard, and the fight was left to the local city government to limit polluting vehicle use in their roads.

3.1 Milan

Milan, and since 2008, has implemented the Low Traffic Zone policy. First, from 2008 to 2011 through the Ecopass program, which is mainly a pollution charge in the specific Limited Traffic Zone. Later, in 2012, the scheme was substituted by a congestion charge policy Area-C. The Ecopass's fare was variable (between 2, 5 and 10 EUR), while it is flat (5 EUR) for the Area-C policy. Table 1 presents the Area-C scheme, its period and concerned vehicles. The table showed the simplicity of the Area-C scheme, which makes it easy to be adopted by many cities. Generally, both policies had good environmental impacts, as they reduced both traffic and emission, especially at their start. Ecopass was estimated to have lowered PM_{10} emissions by 15%, while Area-C reduced it by a further 18% after the first, in 2012 compared with 2008.

The result of the Area-C scheme could be summarized as: 37.7% of traffic reduction compared to 2012 (Lanzani, 2016) and 9% from 2016 to 2018, a 49% contaminants decrease, reduction of pollutant emissions (-18% of PM_{10}; -18% of NO_X; -35% of CO_2), and a 6.1% increase of cleaner vehicles (from 9.6% to 16.6% of all vehicles).

Table 1: Area-C Scheme

Area	Central Ring
Time	7.30 am to 7.30 pm (no change on weekend and public holidays)
Charge	5 EUR (the payment allows to travel the whole day in the charged area)
Vehicle	- Free entrance for electric and hybrid - Entrance forbidden for gasoline pre-euro, diesel pre-euro, euro I and II

3.2 Rome

In 1989, the city of Rome introduced the Limited Traffic Zone (LTZ) policy to reduce the number of cars circulating and polluting the central area. Firstly, signs were installed, but their inefficiency they were substituted by physical gates using an Access Control System (ACS) under the police control, in 1994. However, the enforcement could not be achieved, so the automated ACS was adopted in 1998, and implemented in 2001. Rome had seven distinct zones, each with its own rules. Only taxis, disabled's vehicles, and residents who live or work in the area have access to enter LTZ areas in Rome's historic centre.
Rome's traffic policy involved five concentric zones, each with different rules. In the historical area, different measures have been adopted to restrict the access of private vehicles, and to enhance public transit. Along the railway-ring, parking pricing is enforced, and non-catalysed vehicles are prohibited. While at ring-road, an extensive system of park-and-ride lots and public transit facilities have been developed. In 2014, Rome evaluated its LTZs policy using several criteria, and the evaluation showed: a 5% reduction of car trips, a 3.6% increase of public transit trips, and a 1.5% increase of pedestrian and cycling trips (DeRobertis and Tira, 2016).

3.3 Paris

First Paris has implemented a policy called Paris-Respire in 2017 within the Butte-aux-Cailles neighbourhood. This policy is about banning some area access by cars on Sundays and other holidays. Later, as a wider policy to control the air quality, the government of Paris has adopted a low emission zone program (ADEME, 2014), which relies on the access vignette system, and where zones were divided into two types: Zones with Restricted Circulation (ZCR), and Zone with Air Protection (ZPA).
The difference between these two zones is noticed regarding the vignette Crit'Air 5, where all vehicles can enter ZPA, but almost only high occupancy vehicles and heavy vehicles can enter ZCR.
There are six vignette classes, according to the European Emission Standards, that permit vehicles with some specific characteristics to enter the environmental zone. In every zone's entry, there is the anti-pollution police to control vehicles and verify vignettes (Mairie De Paris, 2017).
The following Figure 1 shows all existing vignettes Crit'Air categories and display the characteristics of vehicles for each category.

	Crit' Air Green Vehicles 100% electric or hydrogen vehicles
1	**Crit' Air 1** Euro 5 & 6 petrol vehicles (registered before Jan 1st, 2011)
2	**Crit' Air 2** - Euro 4 petrol cars (registered between Jan 1st, 2006 and Dec 31st, 2010) - Euro 5 & 6 diesel cars (registered before Jan 1st, 2011)
3	**Crit' Air 3** - Euro 2 & 3 petrol cars (registered between Jan 1st, 1997 and Dec 31st, 2005) - Euro 4 diesel cars (registered between Jan 1st, 2006 and Dec 31st, 2010)
4	**Crit' Air 4** - Euro 3 diesel cars (registered between Jan 1st, 2001 and Dec 31st, 2005)
5	**Crit' Air 5** - Euro 2 diesel cars (registered between Jan 1st, 1997 and Dec 31st, 2000)

Figure 1: Vignettes' Characteristics in Paris

There are six categories: Crit'Air 1, 2, 3, 4, 5, and Crit'Air for green vehicles, which has been considered for the vehicles' banning process. The system of vehicles' banning, has been implemented in four steps. First, the city of Paris has banned every vehicle with no vignette. Then, it has eliminated vehicles with vignette 5. Later, and since July 2018, vehicles with vignette 4 have been banned. And finally, all vignettes 3, 4 and 5 have to be banned from circulating. Paris LEZ policy's ultimate goal is to eliminate diesel vehicles completely and only permit vehicles with vignette Crit'Air 1 or Crit'Air green vehicles to run by 2020.

3.4 London

London has implemented the LEZ policy in phases since 2008. The policy covers most of Greater London, and it is enforced 24 hours a day, including weekends and holidays. It mainly forces vehicles to either meet the emission standards or pay a daily charge that can reach EUR 110. London is planning to raise the charge by 2020, especially for larger vans and heavy vehicles that do not meet the emission standard.
However, two pollutants are still causing great concern in London area: Nitrogen Dioxide (NO_2) and Particulate Matter (PM) (TfL, 2017), London government was forced by the UK supreme court, to revise NO_2 action plan draft (TfL, 2017).
Hence, London introduced an upgrade of its LEZ policy called the Ultra-Low Emissions Zone (ULEZ) in April 2019. Similarly, this new policy requires all motor vehicles to meet emission standards or pay daily charges, except taxis that have their specific requirements through the taxi licensing system. Besides, the ULEZ introduces new charges for certain vehicles driving within the same boundary as the CCZ, where the daily fare for ULEZs is an addition to any applicable congestion charge or LEZ charge (TfL, 2017).
The new charging strategy applies to gasoline vehicles that do not meet the Euro 4 emission standards, and to diesel ones that do not meet the Euro 6 emission standards. In October 2021, the ULEZ policy is intended to expand from central London to the boundary of the north and south (Morton et al., 2017).

4. Discussion

The first characteristic of the LEZ policy is the restriction or ban of pollutant vehicles, based on their emission levels, from entering the designated zones. The second characteristic is that banned vehicles cannot buy their way in, as the case with congestion pricing. Therefore, the first goal of such a policy is the reduction of air pollution, while relieving traffic congestion comes after. However, in reality, the LEZ policy is used, first to limit the number of circulating vehicles. Then, to guarantee the ban of the majority of grossly pollutants vehicles.
In order to respond to air pollution's increase; most cities are forced to implement short-term and long-term measures. Therefore, many cities adopted the LEZ policy, as of January 2018, Berlin, Brussels, Lisbon, London, Milan, Oslo, Paris, and Amsterdam (only taxis) have an active LEZ. Besides, congestion charges (CC) are in force in Athens, London, Milan, Stockholm, and Oslo. Some have even announced an outright ban of diesel vehicles, with Oslo scheduling it as early as 2019, Paris in 2024, and Athens and Madrid in 2025.
Table 2 provides a summary of the LEZ policies in London, Paris, Milan, and Rome. The table helps also make a quick comparison between the mentioned cities. Rome has the most complicated scheme compared to others. Milan seems the only city that has introduced both congestion and the parking charges to support the LEZ policy. All cities seem to have no ban against diesel Euro 6, which was considered by some researchers, the first reason behind the failure of the European LEZ policies. Moreover, the option of paying to enter bring the equity issue to light and prevent from achieving the goal of clean air. Cities like Milan, Rome, and London could be considered successful cases, as they got the best results of reducing traffic emissions.

Table 2: Low Emission Zone policy comparison between London, Milan, Paris, and ROME

	LONDON	MILAN	PARIS	ROME
Area	most of London	71% of Milan	All Paris	Total area is about 5 Km^2
Type	LEZ (& CC)	LEZ (& CC)	LEZ	LEZ (& CC)
Rules	Pay to enter Or meet standard	CC & parking charge + access restriction	Pay to enter (vignettes for all)	CC & parking charge + access restriction
Banned Vehicles	< Euro 6 diesel And <Euro 4 petrol	- Euro 4 diesel - No access for freight vehicles (8 am – 10 am) and bulky vehicles (Monday-Friday, 7.30 am to 7.30 pm)	Diesel except Euro 5&6 (will be banned in 2020)	Each zone has its own rules

Their success keys are simplicity and efficiency. However, Paris's policy is still a new one, which prevents from providing a fair judgment. Most cities have a low emission zone and some a congestion charge to complement. In Milan, Euro-4 diesel vehicles with a filter are currently allowed, but as standards become more stringent retrofits will not be allowed after 1 October 2019. Conversely, Paris and Madrid do not allow any retrofitting. Milan's Area-C is estimated to have resulted in a 19% PM_{10} tailpipe emission reduction and 10% less NO_x in the air.

London has additionally added a toxicity charge and plans to have it replaced by an Ultra-Low Emission Zone (ULEZ) in 2019. The ambitious ULEZ will require all diesel vehicles to pay to enter the city centre apart from those meeting Euro 6 standards.

Despite all the efforts, European cities still far from reaching their goal of eliminating diesel vehicles due to the Euro 6 exemption policy, which represents an obstacle in front of governments. Also, LEZ measures have usually high impacts at their beginnings, but the impact declines sharply after a while because people try to mitigate either their schedules or roads.

The following figure shows the differences between the impacts of the LEZ implementation in different cities. The most improvement was achieved in CO2 and traffic reduction, with Milan's Area-C program as the strongest in that regard.

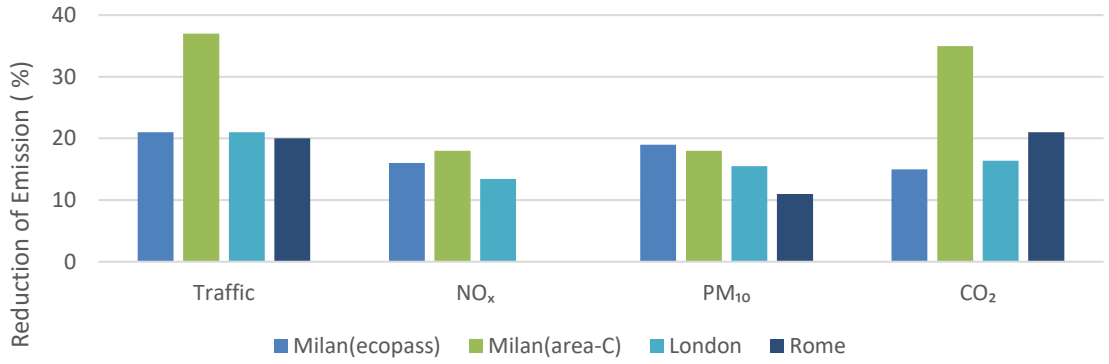

Figure 2: Percentage of emission reduction due to LEZ (London, Milan, and Rome)

5. Conclusions

Despite the implementation of LEZ policies in many European cities, still, no city has reached the accepted limited value of particles: PMs and NO_x. Moreover, many studies that attempted to calculate the real environmental impacts of LEZ policy in the term of emission reduction, cannot find significant changes in emissions. There are many reasons for this inability to reach goals, in which, the difficulty of banning diesel vehicles, because of the big opposition from concerned companies. The T&E (2018) report, highlighted the Euro 6 exemption as the main reason behind the failure of the European LEZ policies. Also, Settey et al. (2019) suggested, for cities with LEZ, to renew the freight vehicles, and use more modern vehicles.

Therefore, applying LEZ policy alone cannot bring miraculous results, however, the policy should be accompanied by other TDM measures, as well as strong regulations and powerful political will. Joining LEZ with other TDM measures will enhance the LEZ efficiency to reduce pollutants. While the strong political and regulations will stop the diesel Euro 6 exemption. T&E (2018) suggested three recommendations, to improve the efficiency of the LEZ policy: first, considering only real-world emissions (RDE) as criteria of vehicles' ban system, second, implementing remote sensing that links the number plate recognition to police compliance, to ensure pollutant vehicles are not permitted in the city, third, providing high quality public transport as well as infrastructure for active, shared and zero emission transport modes.

Besides, several media campaigns are needed to maximize awareness about the environment and promote public transportation, as well as the use of new mobility, either green mobility or shared mobility.

Moreover, the use of new technologies is also highly recommended, such as Vehicle-to-Everything (V2X) technology. As pollutant particles are emitted either during driving, acceleration/deceleration, or stop of a vehicle, signal system management through V2X technology, revealed to play a crucial rule in emission reduction (Kim et al., 2019). Moreover, V2X permits also reducing congestion, and thereby deceleration, and travel time, which means reducing emission. Also, V2X permits reducing parking wasted time, by offering information to drivers, etc. Therefore, the extended usage of V2X and other technologies is highly recommended to improve all TDM measures, and LEZ policy in particular.

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References

Boogaard H., Janssen N.A.H., Fischer P.H., Kos G.P.A., Weijers E.P., Cassee F.R., van der Zee S.C., de Hartog J.J., Meliefste K., Wang M., Brunekreef B., Hoek G., 2012, Impact of low emission zones and local traffic policies on ambient air pollution concentrations, Science of the Total Environment, 435–436, 132-140.

DeRobertis M., Tira M., 2016, Traffic restricted zones in Italy, Institute of Transportation Engineers (Annual Report Issue), 86 (12), 44-49.

European Environment Agency (EEA), 2014, Air quality in Europe, Annual report No 5/2014, Luxembourg.

Fan Y.V., Klemes J.J., Perry S., Lee C.T., 2018, An emissions analysis for environmentally sustainable freight transportation modes: distance and capacity, Chemical Engineering Transactions, 70, 505-510.

French Environment and Energy Management Agency (ADEME), 2014, Etat de l'art sur les peages urbains, <ademe.fr/sites/default/files/assets/documents/etat-art-sur-peages-urbains-2014.pdf> accessed 02.10.2019 (in French).

Holman C., Harrison R., Querol X., 2015, Review of the efficacy of low emission zones to improve urban air quality in European cities, Journal of Atmospheric Environment,111, 161-169.

Kim J., Jung S., Kim K., Lee S., 2019, The real-time traffic signal control system for the minimum emission using reinforcement learning in V2X environment, Chemical Engineering Transactions, 72, 91-96.

Lanzani G., 2016, Milan and Lombardia air quality: analysis and prospective in reference to measures to reduce the impact of traffic, Agenzia Regionale per la Protezione Ambientale Lombardia, Valencia, Italy.

Mairie De Paris, 2017, Le bilan des déplacements en 2017 à Paris, Direction de la Voirie et de Déplacements, <temis.documentation.developpement-durable.gouv.fr/docs/Temis/0033/Temis-0033289/8724_2017.pdf> accessed 02.10.2019 (in French).

Meyer M.D., 1999, Demand management as an element of transportation policy: using carrots and sticks to influence travel behaviour, Transportation Research Part A: Policy and Practice, 33 (7-8), 575-599.

Mohammad Rozali N., Wan Alwi S., Ho W., Manan Z., Klemeš J., 2015, Expansion of a diesel plant into a hybrid power system using power pinch analysis, Chemical Engineering Transactions, 45, 343-348.

Morton C., Lovelace R., Anable J., Exploring the effect of local transport policies on the adoption of low emission vehicles: Evidence from the London Congestion Charge and Hybrid Electric Vehicles, Transport Policy, 60, 34-46.

Organisation for Economic Co-operation and Development (OECD), 2010, Transport regulation from theory to practice: general observation and case study, Discussion Paper 2010-19, <itf-oecd.org/transport-regulation-theory-practice-general-observations-and-case-study > accessed 02.10.2019.

Sadler L., 2014, LEZs in Europe, Sadler Consultants Ltd, <slideshare.net/STEP_scotland/lucy-sadler-lez-talk-scotland2> accessed 02.10.2019.

Sävbark B., Ahlvik P., Eriksson L., 2006, Assessment of Environmental Zone in Goteborg, A report for the Traffi c & Public Transport Authority of the City of Göteborg, Stockholm, Sweden.

Settey T., Gnap J., Beňová D., 2019, Examining the impact of the deployment of low emission zones in Europe on the technological readiness of road freight transport, Transportation Research Procedia, 40, 481–488.

Transport & Environment (T&E), 2018, How to get rid of dirty diesels on city roads, Analysis of diesel restriction measures in European cities to date <transportenvironment.org/sites/te/files/publications/TE%20Air%20Quality%20Report_FINAL_12032018%20NEW.pdf> accessed 02.10.2019.

Transport for London (TfL), 2017, Changes to Low Emission Zone and Expansion of the Ultra Low Emission Zone, supporting information document, < https://www.london.gov.uk/sites/default/files/appendix_c1_supporting_information_document_-_copy.pdf> accessed 13.11.2019.

Ungemah D., Dusza C., 2009, Transportation demand management benchmark: results from 2008 TDM program survey, Transportation Research Record, 2118(1), 55–66.