

Zoned Traffic Limitation Plan (LEZ) to mitigate the increase in traffic congestion on the main roads in the center of Guayaquil

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Abstract—The center of Guayaquil faces a growing problem of traffic congestion on its central roads; to mitigate this problem it is intended to design low emission zones (LEZ) within the center of the city of Guayaquil since these can help control traffic congestion and improve air quality in urban areas. In general terms, Low Emission Zones consist of traffic management, so they are designed to reduce the number of highly polluting vehicles circulating in specific areas of a city. They work by restricting the entry of vehicles that do not meet certain emission standards or do not have environmental labels, vehicles with high emissions are not allowed to enter or have limited access to specific areas. This reduces the number of polluting vehicles in those areas, decreasing congestion. Implementing low-emission zones in downtown Guayaquil could help control traffic congestion by discouraging high-polluting vehicle traffic and promoting more sustainable forms of transportation. In Ecuador, this measure has already been implemented with very positive results, however, its effectiveness will depend on adequate planning and integration with other urban mobility measures.

Keywords: Traffic congestion, air quality, traffic, urban mobility.

INTRODUCTION

The city of Guayaquil, capital of the province of Guayas, is considered among the largest cities in the country and the fifth largest in the Andean community. Its population is between 2,746,500 inhabitants according to the 2022 Population and Housing Census. Given its demographic increase and the boom in commerce in the central zone, there are several serious problems for this population, vehicular congestion would be one of the main ones since it would be directly affecting the main roads where most of its inhabitants circulate (Primicias, 2023).

Traffic congestion is caused by population growth, the lack of road work such as alternate routes, non-existent or outdated traffic signals, an increase in the vehicle fleet, lack of road maintenance, lack of urban planning, the use of public spaces for commercial activity and the deficiency in the public transport system. Currently, in the city of Guayaquil there are 67 cooperatives and public land transport companies, urban passengers and with 107 bus lines circulating through the city, in addition, the “Metrovía” transport system

operates with 163 of the 332 available buses, according to Bolívar Valarezo, who is the administrator of the system (Menéndez, 2023).

The objective is to reduce traffic congestion and improve air quality in the center of Guayaquil through the implementation of Low Emission Zones (LEZs). In this sense, an investigation is carried out and through this it is proposed to propose possible solutions that improve the level of service and reduce congestion in the central area of the city. There are 3 case studies that promote the Low Emission Zone (LEZ) plan, the case studies are in the cities of Madrid, Spain and Paris, since they have had excellent results with this implementation (Sánchez, 2019).

“These are areas in which access to certain vehicles is restricted due to their emissions, that is, they are measures designed to improve air quality. They are limited to a wide area within the city, or even the entire city, and allow entry to vehicles that meet the best emission standards” (Bárcena et al., 2022)

Implementing Low Emission Zones imposes restrictions on access to highly polluting or less emissions-efficient vehicles. This can include older or highly polluting diesel vehicles. By limiting or prohibiting the entry of these vehicles, the amount of traffic in the area will be reduced. LEZs often go hand in hand with improvements to public transport and infrastructure for cyclists and pedestrians. By offering attractive alternatives to car use, such as efficient public transport, safe bike lanes and pedestrian areas, people are being pushed away from opting for more sustainable means of transport instead of their personal cars. Public awareness of the importance of reducing emissions and pollution can lead to behavioral change. People may choose to use public transport or cleaner modes of transport, such as carpooling or bicycles, instead of their private vehicles, which helps to reduce congestion.

In conclusion, the plan intends to be implemented in the central zone in order to mitigate the consequences of road congestion associated with the reduction of vehicle traffic speed, the delay in travel times, as well as, increases in: traffic accidents, additional fuel consumption, wear and tear of road works, greater environmental pollution, affect the quality of life and health of users who circulate in the direction of the central area of Guayaquil. Therefore, it will be necessary to study the operability of the traffic flow, or level of vehicular service to find solutions that modify the perception by users, as well as the speed, flow condition, volume of service, travel time and possibility of maneuvering.

MATERIALS AND METHODS

a. VEHICULAR CONGESTION

Traffic congestion directly affects the country's road network, it is one of the main problems for the population and citizens who circulate in these spaces, it significantly impacts urban mobility and the quality of life of its inhabitants (Inca López, et al 2023).

This problem arises due to various causes such as:

- Population Growth
- Expansion of business activities
- The lack of workability in alternative road solutions
- Inadequate traffic signaling
- Increase in the vehicle fleet
- Saturation of main roads at peak hours

This situation is reflected in the stress produced by long travel times and the inefficiency of public transport. In addition, it has a great impact on air pollution, the deterioration of environmental quality and the repercussions on the health of the inhabitants.

b. SUSTAINABLE MOBILITY

The concept of sustainable mobility can be defined considering the integration of environmental limits not only within transport policy but also in all those on which mobility has an impact. Within a sustainable development model, sustainable mobility can be defined if its impact on the system is considered.

Agenda 21 establishes a series of minimum objectives to channel a process towards sustainable mobility:

- Integrate land use and transport plans to reduce transport demand
- Adopt programs that favor public transportation
- Encourage the use of non-motorized means of transport
- Prioritise effective traffic management, efficient operation of public transport and maintenance of transport infrastructure.
- Reassess current patterns of production and consumption

The European Commission defines sustainable mobility as a system and patterns of travel that provide the means and opportunities to meet economic, environmental and social needs in an efficient and equitable way, while minimizing unnecessary adverse impacts and their associated costs, within the relevant spatial and temporal scales. In other words, sustainable mobility is one that reduces the need to travel to the physical and environmental limits of the territory, while prioritizing the use of more efficient modes of transport, which are accessible to the community and that favor the economy of the territory (Guillamón & Hoyos 2005).

c. LOW EMISSION ZONES (LEZS)

Low Emission Zones are those urban areas in which measures are implemented to control and reduce CO2 emissions, i.e. access to certain vehicles is restricted due to their emissions, they are measures designed to improve air quality and reduce environmental pollution in specific areas of the city.

This concept became relevant due to the growing concern about climate change. At the end of 2015, the European Commission reached an agreement stating that the signatory countries during the COP21 (United Nations Conference on Climate Change) would begin to take real measures on climate change issues. This agreement is called the "Paris Agreement", which seeks to stop the increase in the planet's temperature because of various pollutants. From here, the so-called LEZs (Low Emission Zones) emerge as an initiative that promotes areas where pollution is below the maximum pollution level (Gallego Reina, 2022).

d. INTERNATIONAL CASES

MADRID

Country: Spain

Community: Community of Madrid

Province: Madrid

Municipality: Madrid Capital

The LEZs in the municipality of Madrid Capital are currently operating within the municipality and not covering the whole of it. The measures are carried out around the M-30 motorway in the inner part, which overlooks the city center, it should be noted that one of the LEZs is a border and serves as access to an A-42 national motorway.

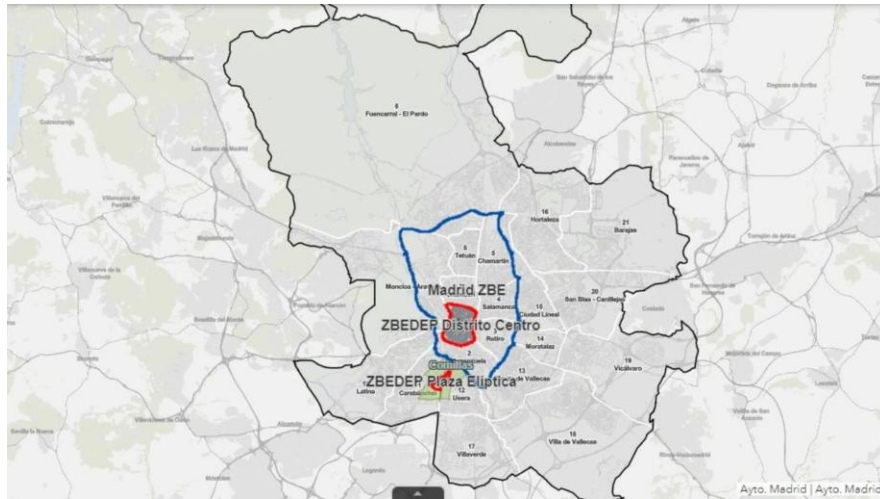


Fig. 1. Location. ZBE Madrid Source: PDOT Madrid, 2022.

Technical Information of the municipality of Madrid Capital

Inhabitants: 3,223 million inhabitants

Proposed Low Emission Zones: M-30 inner LEZ, ZBEEP Distrito Centro and ZBEEP Plaza Elíptica.

Initiation of measures: 30 November 2018

Urban Improvements:

- 3 public transport lines are proposed, with 100% electric buses
- Increase in charging points for electric cars, the use of this means of transport encourages the use of alternatives for mobilization and discarding polluting fuel.

BARCELONA

Country: Spain

Community: Catalonia

Province: Barcelona

Municipality: Barcelona and surrounding areas

The LEZs in the municipality of Barcelona cover an area of more than 95 km² where the circulation of polluting vehicles is restricted to protect the environment. It covers the entire city of Barcelona from the Ronda de Dalt and the Ronda del Litoral, part or all the municipalities of L'Hospitalet de Llobregat, Cornellà de Llobregat, Espluges de Llobregat and Sant Adrià de Besos.



Fig. 2. Location of the Barcelona LEZ Source: RACE, 2023.

Technical Information of the Municipality of Barcelona

Inhabitants: 1,620 million inhabitants

Proposed Low Emission Zones: Barcelona Ring Roads LEZ.

Initiation of measures: Start of Phase 0 – 1 December 2018

Urban Improvements:

- The Superblock or Super block project is proposed, it is the selection of some squares that will be converted into spaces of vegetation and the streets that emerge from the square will become pedestrian areas.

PARIS

Country: France

Region: Île-de-France

Apartment: Paris

The LEZ is bounded by the A86 motorway, which has a large conurbation around the capital of. As each administrative unit decides separately to incorporate a zone, the low emission zone is currently valid in only 47 municipal districts. However, it is expected that more municipalities will also implement these zones.



Fig. 3. LEZ Paris Signage Source: Le-Fayette, 2020.

Technical Information of the Municipality of Barcelona

Inhabitants: 2,161 million inhabitants

Proposed Low Emission Zones: Zone 1,2,3,4.

Start of measures: 1 January 2016

Urban Improvements:

- It is proposed in about 180km more of bike lane, under the name of the *Bike Plan Project*
- Anne Hidalgo, Transformation of the Champs-Élysées called "Extraordinary Garden", the project seeks to eliminate four of the eight existing lanes intended for vehicles to make them for pedestrians.
- Anne Hidalgo, City of 15 minutes; He proposes that all needs should have a minimum ratio of 15 minutes.

e. URBAN CONTEXT OF GUAYAQUIL

The project is in the city of Guayaquil, in the urban parish of Rocafuerte, within the polygon that is delimited by 9 de Octubre Avenue, Simón Bolívar Avenue and Francisco Aguirre Abad and Lorenzo de Garaycoa streets.



Fig. 4. Location context study. Note: Prepared by the authors.

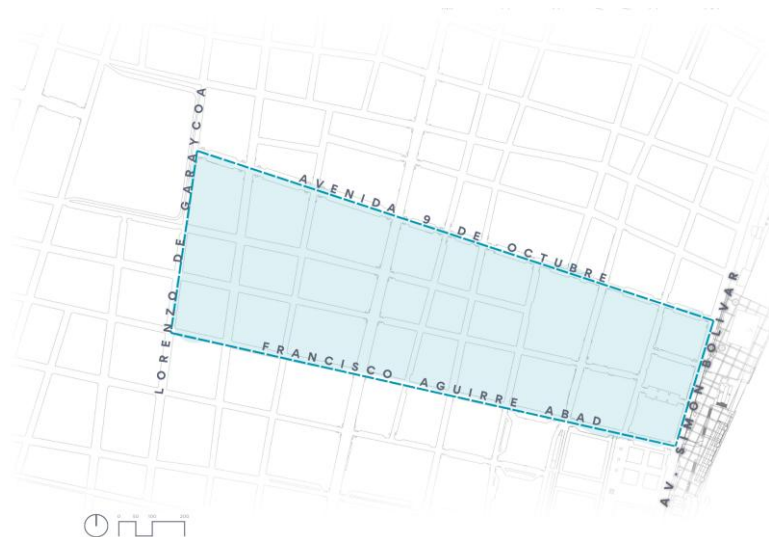


Fig. 5. Area to be intervened. Note: Prepared by the authors.

Guayaquil, a city in constant growth and economic development, faces important challenges within its urban context, accelerated population growth and territorial expansion without prior planning make the city center become a critical point of the city. The concentration of commercial and residential activities at the test site contributes to traffic congestion and leads to environmental problems related to air quality in these densely populated areas.

The project has the following objectives:

- Develop a new road plan to manage and promote zoned traffic limitation (LEZ)

Specific Objectives:

- Design a network of horizontal and vertical axes in the city center so that they connect residential, commercial and tourist areas.
- Reduce the number of highly polluting vehicles circulating in specific areas of a city.
- Generate secondary roads parallel to the main roads to mitigate the traffic generated by the increase in vehicles.

To analyze more fully the road dynamics that develop in this area, various means were used to collect information, such as analysis of traffic rates at the site, collection of information through bibliographic sources and field visits.

To identify the critical points of congestion and the areas most affected by the high levels of vehicular pollution, the number of vehicles circulating in the area and the traffic rates in the sector were analyzed.

Three records were taken from one day of the week with a lapse of five hours between records, with data collected on the site and technological support tools, the data they yielded were reflected as follows:



Fig. 6. Traffic index, Tuesday 7am. Note: Prepared by the authors.

The site does not have a large influx of cars, it can be traveled normally, and vehicular traffic can be classified as medium-low because there is no evidence that any street has a high traffic index.



Fig. 7. Traffic index, Tuesday Noon. Note: Prepared by the authors.

At peak hours, the analysis site has a much higher rate of vehicles, the streets show traffic congestion and pedestrians find it difficult to travel through the area. Certain aspects of the context must be considered, the lunch schedule of the people who work in the place and the departure time of the students belonging to the educational institutions in the area.

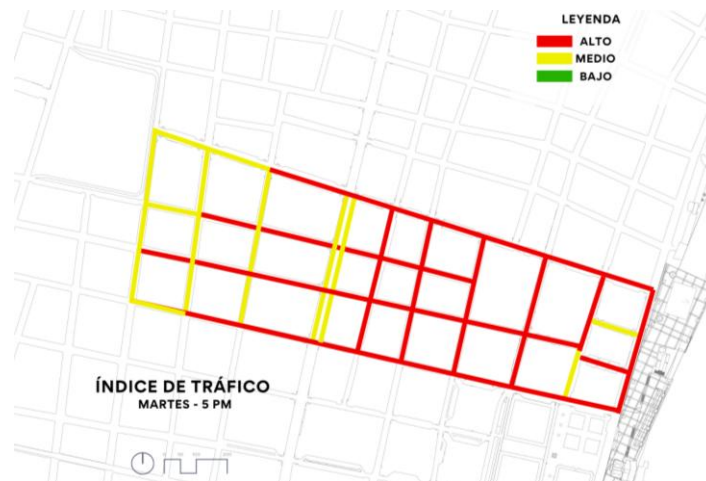


Fig. 8. Traffic index, Tuesday 5PM. Note. Prepared by the authors.

Traffic congestion at the analysis site is evident, long travel times, noise and environmental pollution, delays in the arrivals of the public transport network and difficult pedestrian mobility.

Although downtown Guayaquil is positioned as an important point in the historical and commercial field, its urban dynamics present challenges in terms of accessibility, safe and sustainable mobility, efficient public transport and planning measures.

RESULTS

LEZs not only have a local impact but also a global one. They must be part of a broader set of sustainable mobility actions and policies at municipal, metropolitan and regional levels, to achieve socio-environmental objectives. However, everyday mobility also depends on policies beyond the local level. In addition to providing a framework for action and economic support for local governments to implement, these policies can have a strong impact, such as establishing expiration dates for combustion vehicles. This would be an incentive for cities to progressively introduce Low Emission Zones.

Traffic congestion in large cities is an urgent problem to solve. The pandemic increased the use of private vehicles for fear of contagion on public transport. With the de-escalation, the traffic jams, noise and pollution typical of urban centers returned LEZs seek to contribute to mitigating climate change by reducing polluting emissions and noise, improving air quality. They do this by promoting public transport, more sustainable vehicles and safe mobility for pedestrians and cyclists.

Through strategically placed traffic cameras and emission sensors, the LEZ system will provide predictive data on traffic and pollution. With this information, measures can be adopted to manage traffic and avoid traffic jams and traffic congestion. Based on the "polluter pays" principle, the next step after implementing LEZs would be to incorporate tariffs for driving in some areas. These rates or Congestion Charge vary depending on factors such as the environmental label, the time of entry or the specific area being accessed.

One of the immediate effects of its implementation is to discourage the most polluting cars from entering the LEZs, thus reducing congestion, pollution and, as there is less traffic, accidents. The project of low emission zones will be carried out in a coordinated manner between the metropolitan area of Guayaquil and

the central zone, as the most congested area the intervention in the streets 9 de Octubre, José Vélez and Gabriel José de Luque was proposed, with the integration of a technological control model, this will have as main objectives:

1. Creation of a metropolitan portal of exemptions and authorizations

Common exemption databases will be created. In accordance with jointly established exemption criteria, a tool will be developed to update the database and allow citizens to apply for exemptions.

2. Development and maintenance of the metropolitan LEZ management platform:

This would be with the creation of an application that allows the integration of various services, and the processing of license plate records received from the chambers of the metropolitan area. On this platform, the cameras and control devices of the low emission zones will be recorded and the logics for sanctioning vehicles will be established, which may vary over time or according to pollution episodes. The general logic is that those vehicles that comply with the following will be considered punishable: having restricted circulation by environmental badge or homologation, or foreign license plate; not having been previously captured by another camera on the same route; and not being exempt or having authorization for that day in the Metropolitan Registry.

3. The web service for asynchronous validation of vehicle license plate records captured by cameras

It will allow the municipality to send daily the readings of car license plates taken by fixed cameras installed in low emission zones (LEZs). It also processes records made from vehicles or other devices. The service returns a list of possible detected violations. The return information includes data necessary to define the type of infringement applicable according to the category of vehicle approval, pollution episodes, etc.

The effectiveness of this system is predicted in the short term, taking as references the success in other large cities such as London. It currently has integrated both LEZs and Congestion Paying, and in three years it has reduced the number of polluting vehicles by 50%. The decrease in traffic has reduced nitrogen dioxide (NO₂) emissions by 44% and has improved air quality. The revenues obtained from the Congestion Payment are being used to improve the public transport system, the provision of more bike lanes and new urban spaces that allow for greater pedestrian infrastructure.



Fig. 9. LEZ Signage. Note. Prepared by the authors.



Fig. 10. Area of intervention, aerial view. Note. Prepared by the authors.



Fig. 11. Area of intervention, view 2. Note: Prepared by the authors.

DISCUSSION

The implementation of Low Emission Zones (LEZs) is a fundamental strategy to address the problem of traffic congestion in large cities, with benefits both locally and globally. This approach is particularly relevant in the current context, where the pandemic has intensified the use of private vehicles due to the fear of contagion on public transport, exacerbating the problems associated with traffic, noise and pollution. The discussion on LEZs must go beyond the purely local level, recognizing that solutions to sustainable mobility must be part of a broader framework involving actions at municipal, metropolitan and regional levels. In addition, it is essential to consider policies at the global level that complement local actions, such as setting expiry dates for combustion vehicles, which could provide an additional incentive for the progressive implementation of LEZs in cities. Importantly, everyday mobility is not limited to local borders and depends on a combination of coordinated actions at different levels of government. In this sense, the role of LEZs is not only focused on reducing traffic congestion but also contributes significantly to addressing climate change by reducing polluting emissions and noise, thus improving air quality.

- Data collection using traffic cameras and emission sensors in LEZs provides valuable information for efficient traffic management and informed decision-making. This technology will not only make it possible to anticipate and prevent congestion, but also to apply specific measures to improve mobility, promote public transport and guarantee the safety of pedestrians and cyclists.
- The introduction of tariffs for driving in certain areas, based on the "polluter pays" principle, represents an additional step towards sustainability and the reduction of highly polluting vehicles. Not only do these fees act as a deterrent for the most polluting vehicles, but they can also generate revenue that can be reinvested in sustainable mobility initiatives.
- Collaboration between metropolitan areas, as proposed in the case of Guayaquil, demonstrates the need to address traffic congestion in a comprehensive and coordinated manner. The intervention in specific streets using a technological control model reflects a modern and efficient approach to the successful implementation of LEZs. However, ensuring active community participation and transparency in implementation is critical to ensuring the long-term success of these initiatives.

CONCLUSION

In conclusion, the implementation of Low Emission Zones (LEZs) is presented as a comprehensive and necessary strategy to address the urgent problem of traffic congestion in large cities, especially in the post-pandemic context. The results obtained from this analysis allow several relevant conclusions to be drawn:

- **Comprehensive Approach to Sustainable Mobility:** LEZs should not be considered as isolated measures, but as part of a broader set of sustainable mobility actions and policies at municipal, metropolitan and regional levels. Coordination between these bodies is essential to ensure the effectiveness and long-term success of LEZs.
- **Global Impact of Local Actions:** Recognizing that everyday mobility is influenced by factors beyond the local level, it is crucial to implement global policies that support and strengthen local actions. The establishment of expiry dates for combustion vehicles is an example of a global measure that can incentivise the progressive adoption of LEZs at local level.
- **Post-Pandemic Challenges:** The pandemic has intensified reliance on private vehicles, exacerbating traffic congestion in urban centers. LEZs are presented as an effective response to reverse this trend by promoting public transport, more sustainable vehicles and safe mobility for pedestrians and cyclists.
- **Technology as a Key Tool:** The use of strategically placed traffic cameras and emission sensors

provides valuable predictive data that enables efficient traffic management and the adoption of preventive measures. This technology contributes significantly to improving mobility and reducing congestion.

- Collaboration between Metropolitan Areas: Cooperation between metropolitan areas, as in the case of Guayaquil, reflects the need to address traffic congestion in a coordinated and collaborative manner. Intervention in specific streets with a technological approach demonstrates a modern and effective model for successfully implementing LEZs.

In short, Low Emission Zones not only represent a local solution to traffic congestion but also have a global impact by contributing to socio-environmental goals. Its successful implementation requires a comprehensive vision, collaboration between government agencies and the application of advanced technologies to efficiently manage mobility and improve the quality of life in urban environments.

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