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Review

Are Low Emission Zones Truly Embraced by the Public?

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Abstract: Rapid urbanization and car-centric mobility solutions have resulted in the degradation of environmental urban quality, impacting people's health and well-being and city economies and harming urban ecosystems. Faced with the need to tackle traffic pollution, more than 300 low emission zones (LEZs) have been implemented, causing some social controversy. Nonetheless, researchers have focused their studies on evaluating LEZ efficacy towards urban congestion and air pollutants reduction, health and well-being improvement. This study presents a literature review of what is known about acceptability and acceptance of the population regarding the implementation of LEZs, along with the main issues, best practices, and suggestions to promote a better perception and mobility behavior change. Based on research conducted in the Web of Science and Scopus databases, only 36 of 540 peer-reviewed articles on LEZs address public attitudes. Among the main findings, the following stand out: the existing gap in environmental urban quality approaches between countries, namely the Global North; the existence of few studies that evaluate perceptions before and after LEZ implementation; the lack of LEZ studies that consider noise and biodiversity, seeking a broader approach to this measure; and the importance of developing a support package measures that involves affected stakeholders and are adapted to each city's characteristics.

Keywords: low emission zones; acceptability; acceptance; urban environmental quality

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1. Introduction

With the continuous process of migration from rural to urban areas, it is predicted that by 2050, 68% of the world's population will live in cities [1], with air pollution and environmental noise resulting from intense exposure to traffic-related pollutants being the main causes of degradation in health and quality of life [2–4].

Despite important improvements in air quality, air pollution remains a major health concern in cities in low-, middle-, and high-income countries [5]. In 2021, the WHO updated recommended air quality limits for a range of pollutants [6] because of better knowledge of the potential damage they can cause.

Following the WHO guidance and as part of the European Green Deal, the EU has established environmental air quality standards to be achieved by all members, which are currently being revised to align with the 2021 WHO guidelines [7]. However, in 2021, the percentage of the European urban population exposed to concentrations of air pollutants that exceeded the new recommended WHO limits was 97% for $PM_{2.5}$, 76% for PM_{10}, 94% for O_3, and 90% for NO_2 [8].

The health impacts caused by these air pollutants include respiratory and cardiovascular problems, as well as premature deaths [4,5]. In economic terms, they lead to labor productivity loss and health systems overload. At an ecological level, they impact terrestrial and aquatic ecosystems, resulting in reductions in habitats and biodiversity decreases in urban and surrounding areas [4,9].

In addition to the damage caused by atmospheric pollution, road traffic is the main source of urban environmental noise, with around 20% of the European population being exposed to harmful sound levels [3], negatively impacting the physical and mental health of

people [3,10] and ecosystems [11,12]. Additionally, the transportation sector is responsible for around 26% of the total CO_2 emissions within the European Union, of which almost 72% can be attributed to road transport [13], contributing to global climate change.

If ambient air quality standards are not met, EU states are obliged to take the necessary measures to reduce the concentrations of air pollutants and to prepare an air quality plan that sets out appropriate measures to reduce pollution as quickly as possible [14].

1.1. Low Emission Zones (LEZ)

Faced with the need to change mobility behaviors, different ways of approaching the change to a less polluting mobility model have emerged. Among them, low emission zones (LEZs) are one of the most widely adopted policies and aim to transform urban mobility into a more efficient and sustainable way for the benefit of the urban population while increasing the quality of urban life and the attractiveness of cities.

LEZs are a type of urban vehicle access regulation (UVAR) measure [15] that combines stimulus and dissuasion strategies, making it difficult or penalizing the use of private vehicles, at the same time seeking to make other means of transport more attractive through incentives and improvements [16]. In Europe, 73% of UVARs are low (and zero) emission zones [17]. In 2022, the total number of active LEZs in Europe was 320, with the expectation of reaching 520 LEZs in 2025 because of new national laws in France, Spain, and Poland, which will represent a 58% increase [18]. The number of LEZs worldwide is unknown.

LEZs can be defined as areas within a city where there are restrictions on the operations of some vehicles (access restrictions) or where their operations are deterred through economic charging schemes. They can be implemented in a wide variety of ways and can combine pricing measures, spatial interventions, and other restrictive schemes to limit the access of vehicles in urban areas based on emission levels, size, weight, type, and time of day characteristics [15,19,20]. In Europe, the categorization of vehicles in LEZs has been traditionally based on the Euro class requirements, such as in the London LEZ [15,21]. In the UK, LEZs are also called clean air zones (CAZs).

The first LEZs in Europe were established in 1996 in Sweden, where they are known as environmental zones. Historically, early versions of LEZs exclusively targeted older large diesel-powered vehicles (HDVs), such as buses and heavy goods vehicles. Only in more recent years have LEZs started to include private cars. Outside of Sweden, the first LEZ implemented was the Mont Blanc Tunnel, between France and Italy, in 2002, restricting the circulation of HDVs that did not meet at least the Euro III standard [14]. Restrictions advanced because of the growth of urban areas, the car fleet, and congestion, but mainly because of the knowledge of the damage caused by traffic emissions to health, well-being, and the environment.

As noted by Morton et al. [22], over time, cities have alternated their approach between congestion charges and schemes that differentiate fees or access based on emission levels. For example, London's congestion charge was changed in 2017 to impose a £10 daily charge (toxicity charge) on cars that did not meet the Euro 4 emissions standard. Milan implemented the opposite, first introducing a charge on pollution in 2008 for more polluting vehicles (petrol cars that did not meet the Euro 3 emission standard and diesel cars that did not meet the Euro 4), and later a congestion charge encompassing all vehicles. This alternation indicates that the best approach to implementing LEZs aiming for the necessary reduction in air pollution, noise, and GHG remains unclear.

Certain sustainable transportation strategies can be put into action through broad policies that are pursued at high levels of government and industry. Examples of such policies include fuel or carbon pricing, technological development in vehicles and fuel, and regulations and standards for vehicles and fuel. Other strategies are usually implemented by local or regional governments, especially those related to traffic management and land use [23]. The implementation of LEZs is particularly a problem for local and regional decision-makers since restricting vehicle entry into a given area usually generates reactions from residents, commuters, and businesses in the affected area. To obtain the desired

improvement in urban quality, it is imperative that the population supports the proposal and adopts the implemented measures, under penalty of the measure being discontinued due to lack of effectiveness. Understanding which approaches have had good results in increasing the acceptability and acceptance of LEZ implementation is key to achieving the intended objective.

1.2. Acceptability and Acceptance

In the literature, the terms "acceptability" and "acceptance" are both used to refer to the public's attitude or "degree of support" towards UVAR measures [19]. In fact, the term "acceptability" refers to the a priori perceived use, (i.e., the prospective judgment of a measure that will be introduced in future, without experiencing it), and can also be referred as "ex-ante" behavior. In contrast, the term "acceptance" refers to the actual use and is defined as public attitudes, including their behavior and reactions after the implementation of a policy [20], which can also be referred to as "ex-post" attitude.

Acceptability and acceptance are both key factors for LEZ policies. If, on the one hand, public acceptability is an important factor for transportation authorities in determining if and how policies should be implemented [20], on the other, acceptance can be used to evaluate the performance of an implemented policy and to improve it. Mostly, it can determine whether a policy will effectively modify travelers' behaviors and decisions [19].

1.3. Objective:

Regarding the study of LEZs, researchers have focused their efforts on evaluating the efficacy of implementing LEZs and other policies to tackle traffic-related air pollutants (NO_2, NOx, $PM_{10,}$ and $PM_{2.5}$), as well as the ability of these measures to improve population health and well-being and reduce urban congestions [14,15,24]. However, even though in 2022, there were more than 300 LEZs in only Europe [18] and high social controversy caused by LEZs in many of these cities [25], few articles evaluate the main problems faced by cities regarding public acceptability and acceptance of LEZ implementation.

Aiming to ensure LEZ effectiveness, i.e., ensuring good urban environmental quality, through changing the population's behavior concerning mobility habits, this article intends to present a review of existing articles that address the public acceptability and acceptance of the implementation of an LEZ in their city, highlighting the main approaches used to measure approval/rejection, the main issues faced by cities to implement an LEZ, as well as presenting actions used by cities to promote a better perception of this measure. Finally, this work aims to be a contribution to cities that plan to implement LEZs.

2. Materials and Methods

For the first step, a search was made in the literature using the Web of Science (WoS) and Scopus databases, which have been widely used for performing reviews and are considered consistent repositories when searching for scientific publications. The search was carried out by using the following terms in the abstract: [LEZ; "low emission zone"; "clean air zone"] AND the following terms in all fields: [acceptance; acceptability; rejection; perception; behavior; behaviour; attitude]. The search was restricted to peer-reviewed documents written in English and published as journal articles, conference papers, early access, proceeding papers, review articles, editorial material, correction articles, and book chapters available in both databases until 23 February 2024. As shown in Figure 1, after merging and removing duplicates, 37 documents were obtained in the WoS database and 150 documents in the Scopus database.

The screening process consisted of evaluating the eligibility of the returned documents. Titles, abstracts, keywords, and, whenever necessary, full texts were manually checked to determine relevant documents. Publications were deemed relevant if they predominantly dealt with public acceptance and acceptability (or the lack of them) in any kind of LEZ. Articles were considered not relevant if they focused exclusively on the assessment of pollutant concentration or congestion reduction; on health and well-being improvement;

on predictive models of pollutant behavior; on privacy-preserving systems to avoid fraud on LEZs; in the acceptance of integrated driver assistance systems using LEZs as a case study; in multi-criteria methods and frameworks to select the best policies to tackle urban air pollution; in predictive models of driver's behavior; among others. Documents in both databases without full texts were also excluded. In the end, 36 documents were chosen.

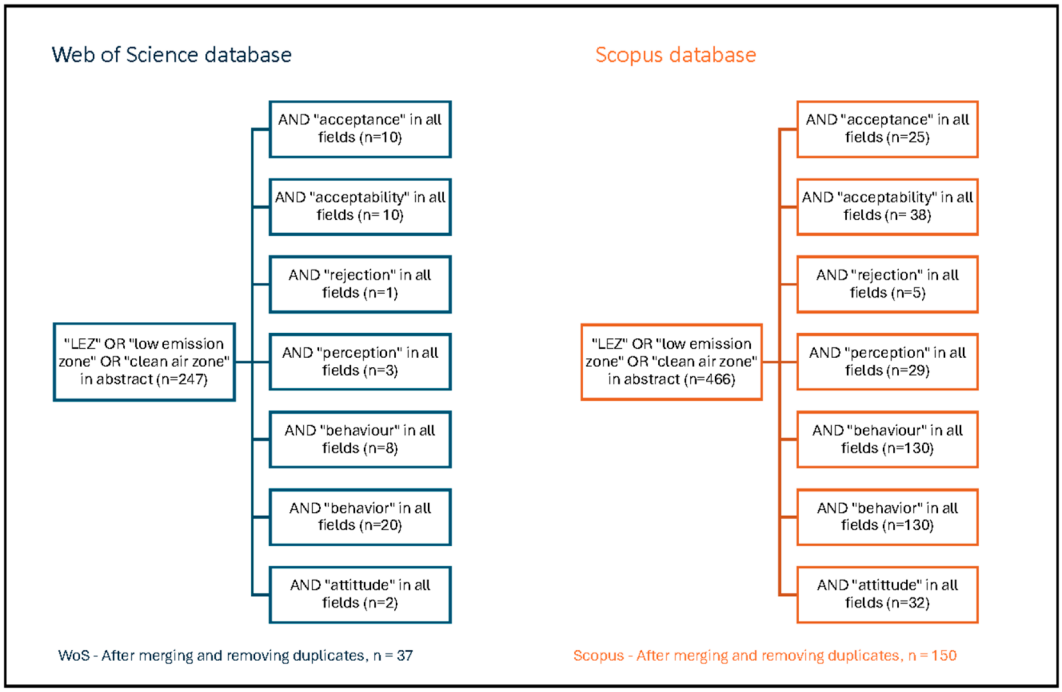

Figure 1. Web of Science and Scopus database research.

Selected articles were then used to conduct a bibliometric analysis to determine relevant data. After that, the extracted articles were classified according to four parameters: urban environmental quality approach, public perception scope, data collection method used, and geographic location of the studied LEZ.

3. Results

When analyzing the 36 selected articles, a significant increase in the number of articles published over time was observed, confirming that although the concept of LEZs was introduced at the end of the 1990s [14], the concern with public perception, before and after the implementation of this measure, has been increasing, particularly since 2020 (Figure 2). It is interesting to highlight that although no time limit was established, it was only in 2014 that the first article was identified.

As expected, given the number of LEZs implemented in Europe, it is observed that the articles mostly address European LEZs, as can be seen in the map in Figure 3. The large concentration of articles focusing on LEZs in the United Kingdom (28%) and Spain (25%) stands out. Outside Europe, there is only one article on a Malaysian LEZ and one on an Indonesian LEZ.

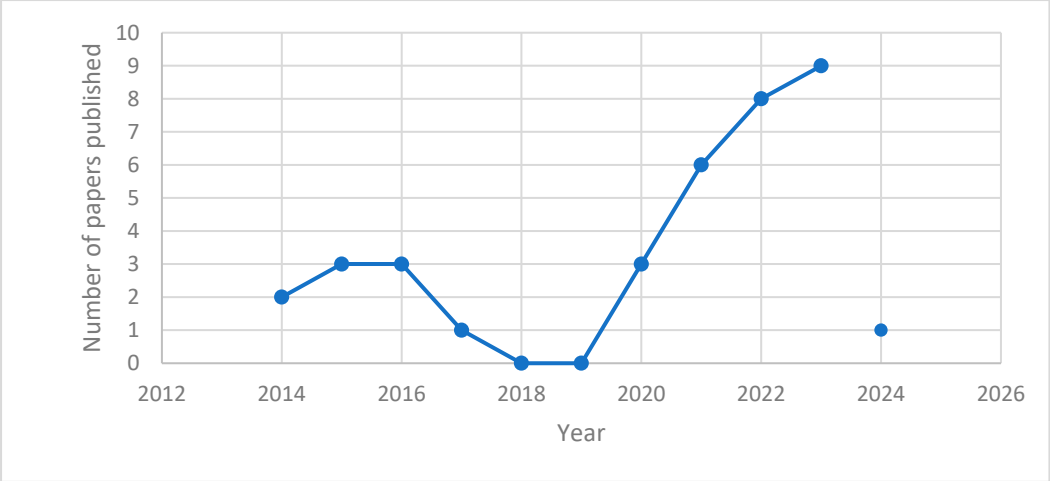

Figure 2. Number of papers published by year (Year 2024 was not considered in the graph line as it only had 2 months of analysis).

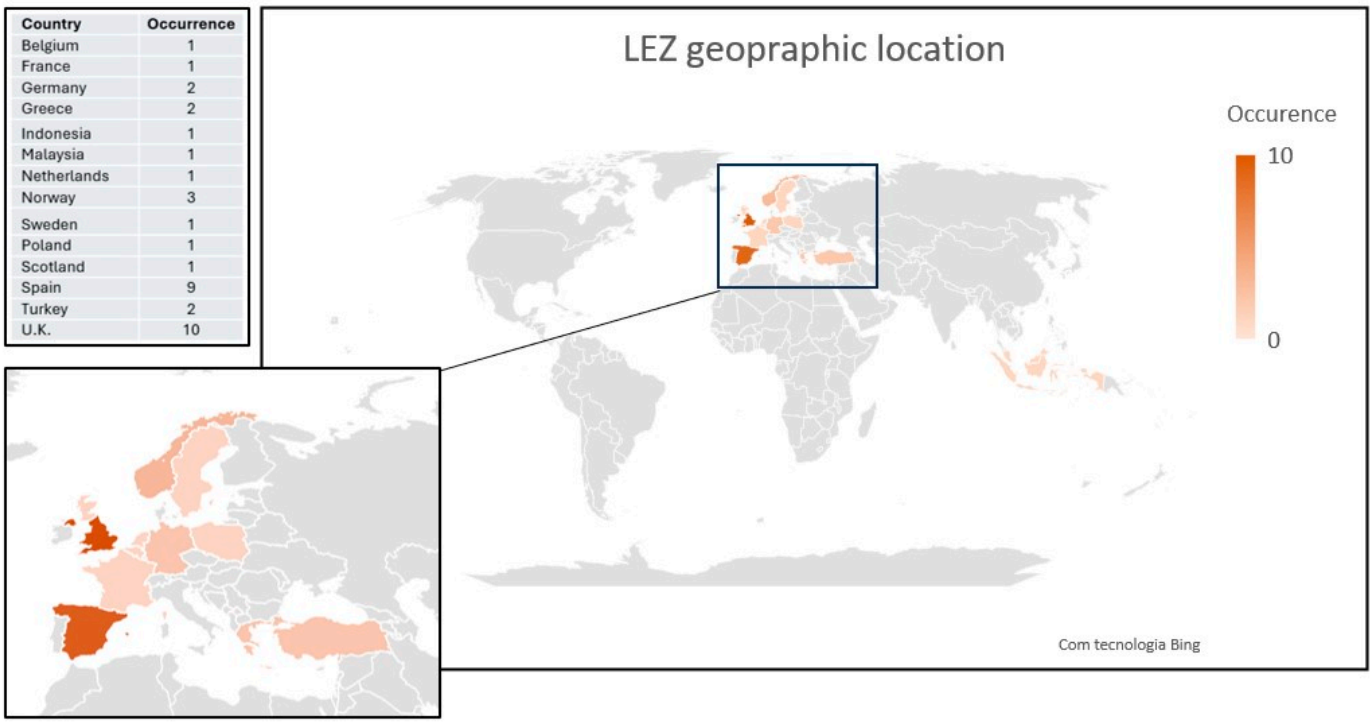

Figure 3. LEZ geographic locations.

Among the analyzed articles, the Keywords Plus (i.e., words or phrases that frequently appear in the titles of an article's references but do not appear in the title of the article itself) with more occurrences is "air quality" (15), followed by "low emission zone" (13), "Spain" (7), and "United Kingdom" (7). When the frequency is analyzed over time (Figure 4), a significant evolution of the term "air quality" can be seen, especially from 2020 onwards. The growth of "air quality", surpassing "air pollution", seems to be a consequence of the implementation of (or the intention to implement) "low emission zones" since the term "air quality" implies a comparison with air pollution standards.

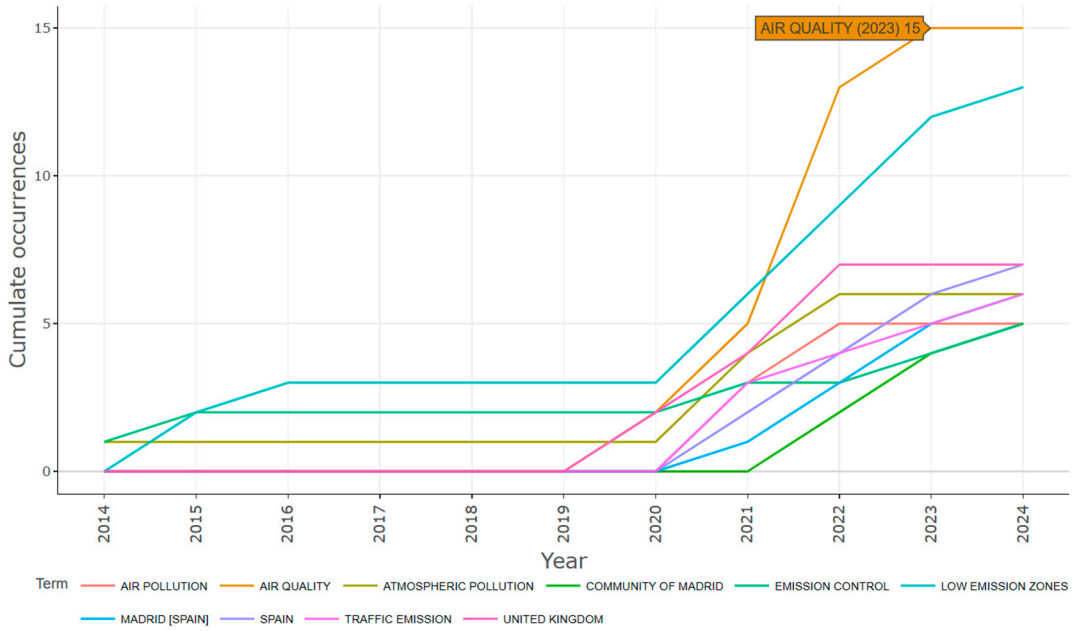

Figure 4. Word's frequency over time.

Of the 36 articles, 86% were articles, and only 6% were review studies. The Polytechnic University of Madrid is the institution with the most publications on the searched topic because of the research performed by José Vassallo, Javier Tarriño-Ortiz, and Julio Soria-Lara about the Madrid LEZ (Spain). The University of York, Bradford Institute for Health Research, and the University of Bradford should also be emphasized because of the research performed by Maria Bryant, Rosemary McEachan, and Rukhsana Rashid about the Bradford LEZ (UK).

Table 1 presents the classification of the 36 selected articles according to their approach to urban environmental quality (air pollution, noise, and/or biodiversity), public perception scope (acceptability and/or acceptance), and data collection method (survey, expert interview, traffic sensors, and other digital data and/or literature review). Additionally, articles were classified based on the geographic location of the studied LEZ.

Table 1. Urban environmental quality approach, scope, data collection method, and geographic location of the researched papers.

Author	UEQ	Scope		Data Collection Method				Geo
	AP/N/B	Acceptability	Acceptance	SU	EI	SE	RW	
Moral-Carcedo [26]	AP		x			•		E
Attia et al. [27]	AP	x	x		•	•		E
Seter et al. [21]	AP	x	x	•		•		E
Gonzalez et al. [28]	AP	x	x			•		E
Jiménez-Espada et al. [16]	AP/N	x		•				E
Oltra et al. [29]	AP	X		•				E
Tarriño-Ortiz et al. [30]	AP	X		•				E
Ding et al. [31]	AP		x			•		E
Mebrahtu et al. [32]	AP	X		•				E
Player et al. [33]	AP	X		•				E
De Vrij & Vanoutrive [34]	AP		x	•				E

Table 1. *Cont.*

Author	UEQ	Scope		Data Collection Method				Geo
	AP/N/B	Acceptability	Acceptance	SU	EI	SE	RW	
Rizki et al. [35]	AP	x		•				As
Ganeshwaari & Koshy [36]	AP	x		•	•			As
Hansen et al. [37]	AP		x	•				E
Kowalska-Pyzalska [38]	AP/N	x					•	E
Gonzalez et al. [39]	AP		x	•				E
Tarriño-Ortiz et al. [40]	AP		x	•				E
McEachan et al. [41]	AP		x	•	•			E
Lurkin et al. [42]	AP		x			•		E
Morton et al. [22]	AP	x		•				E
Oltra et al. [43]	AP		x	•				E
Tarriño-Ortiz et al. [25]	AP		x	•				E
Meelen et al. [44]		x			•			E
Rashid et al. [45]	AP	x		•				E
Ku et al. [46]	AP		x				•	E
Ballantyne &Heron [47]	AP	x		•	•			E
Winter & Le [48]	AP	x					•	E
Sfendonis et al. [49]	AP	x		•				E
Strelau & Köckler [50]			x	•				E
Ambrosch & Leihs [51]		x			•			E
Kilavuz & Kisla [52]	AP	x				•		E
Basbas et al. [53]	AP	x		•				E
Broaddus et al. [54]	AP		x	•				E
Dablanc & Montenon [55]	AP		x	•	•		•	E
Charleux [56]	AP	x				•		E
Tretvik et al. [57]	AP	x		•				E

Urban Environmental Quality (UEQ): AP = air pollution, N = noise, B = biodiversity/Scope: Acceptance, Acceptability/Data Collection Method: SU = Survey, EI = expert interview, SEN = traffic sensors and other digital data, RW = literature review/Geographic Location: E = Europe, As = Asia.

4. Discussion

4.1. Urban Environmental Quality

LEZs aim to improve urban environmental quality, which includes air pollution reduction, noise reduction, and urban ecosystem protection (here resumed as "biodiversity"). For this classification, the presence of the terms "air pollution", "air quality", "noise", and "biodiversity" was considered in the title, abstract, and author keywords of each document.

As expected, 92% of the selected articles' approaches were only related to air pollution/air quality, 6% were related to noise and air pollution/air quality, and none of them were related to biodiversity, as stated in Table 1. Urban environmental quality approach, scope, data collection method, and geographic location of the researched papers.

This finding highlights that for the vast majority of cases, the term "low emission" refers only to a reduction in atmospheric emissions, with few studies also considering noise emissions. A broader approach to LEZs may have greater potential than improving air quality resulting from the implementation of traffic policies.

4.2. Scope

The articles were classified according to the scope of the work carried out, that is, between those that addressed the public acceptability of LEZs and those that addressed public acceptance of LEZs. Studies based on the degree of support of potential LEZs or hypothetical LEZs were both considered public acceptability studies, as they occurred before the implementation of the measure.

Among the 36 articles selected, 19 addressed only acceptability, and 14 addressed only acceptance, which represents 53% and 39% of the articles, respectively.

Although several authors address the need for an assessment of public perception before LEZ implementation and continued monitoring of perception after implementation, it is observed that only three articles (8%) contemplated both stages.

4.3. Data Collection Method

The documents were subdivided into four types of data collection methods: survey (SU), interview with experts (IE), traffic sensor and other digital data (SE), and literature review (RW). It is important to notice that this study focused on the way of obtaining data on acceptance and/or acceptability and not on the methods used to treat or evaluate the data obtained, such as modeling, SWOT analysis, and statistical treatment, among others.

To better fit all articles, semi-structured interviews focused on members of specific groups, such as vulnerable resident groups and retailers affected by LEZs, were considered as "survey methods". In the same way, traffic sensors, vehicle technical data (ex., GNSS position, vehicle presence within zones, speed), cameras-based license checking or counting, transportation card check-ins, bike sharing usage data, and parking payment records were considered as "traffic sensors and other digital data method".

When analyzing the selected documents, there is a clear preference for the use of survey methods (24) against interviews with experts (7), traffic sensors and other digital data (8), and literature review (4) approach. Furthermore, six authors used more than one method to conduct their research, which represents almost 17% of the total.

Some authors who studied acceptability and acceptance tried to identify, through surveys, which individual characteristics or variables (age, gender, social status, mobility travel, etc.) are most relevant to determine or predict greater acceptance or rejection of LEZ implementation, as can be seen in [16,25,43,49].

Amongst the selected articles, it is observed that the expert interview approach is frequently used in mixed data collection methods and intends to explain or validate data obtained from other sources. The expert interview method is also used when a qualitative analysis of the topic is desired.

Of the eight articles that used sensor data as a data collection method, five were in the years 2023 and 2024 (until February), which seems to indicate that this type of method will become increasingly relevant, given the range of behavior indicators that real-time data can provide.

4.4. Geographic Location

Despite most selected studies addressing LEZs in European cities, it was considered that a geographic approach to the discussion could bring a better understanding of the public perception of LEZs, as well as the fear of decision-makers in doing so. In this context, this paper will focus on the Global North (Europe, USA, and Canada) and Asia (Southeast Asia).

4.4.1. Europe

As stated by Tarriño et al. [25], the wide implementation of LEZs in Europe can be mainly explained by the requirements from the EU urban agenda and its legal framework. The European Environment Agency has set annual emission limits for certain air pollutants and has defined that EU member states are responsible for safeguarding these emission thresholds. Specific emissions standards for traffic pollutants have been established, trig-

gering urban transit restrictions implemented by local authorities according to the type of vehicle (from Euro I to Euro VI).

In 2013, the European Commission adopted a clean air policy package. However, it was only in 2018 that a new approach was adopted that provided information and practical support to national, regional, and local stakeholders to improve air quality in Europe [43]. This change, combined with the approval of the European Green Deal in 2020, appears to be the main reason for the increase in the number of articles related to public perception from 2020 onwards.

As previously stated in subchapter 0, of the selected articles, 53% are about LEZ located in the United Kingdom (UK) and Spain.

Faced with a frequent violation of legal annual limits on traffic-related pollutants, such as nitrogen dioxide (NO_2) and particulate matter (PM), the United Kingdom government in 2018 issued directives aimed at local authorities to develop plans to reduce pollution as quickly as possible, through the implementation of "clean air zones" charging. According to the Urban Access Regulations website [58], more than 17 cities in the UK have implemented LEZ, not counting other UVAR measures. This perhaps explains the greater number of studies about this country and also the better geographic coverage. Among ten selected articles about public perception in the UK, five different cities and regions are found.

In 2021, Spain approved the Law 7/2021 of 20 May, compelling all municipalities with more than 50,000 inhabitants to adopt urban mobility plans by 2023, intending to reduce traffic emissions and mitigate GHG, including the establishment of LEZs. Although this law applies to more than 150 municipalities, until 2023, there was still no national criterion that defined the types of vehicles that will or will not be allowed in LEZs, leaving it up to each local council to establish its own restrictions [16].

Of the nine articles that address the public reaction to LEZs in Spain, seven of them were about the Madrid LEZ (also called 'Madrid Central'), which was regulated in 2018, modified in 2020, and since 2021 has been implemented in a phased manner.

4.4.2. North America (USA and Canada)

Unlike Europe, in Canada and the United States of America (USA), the concept of LEZs is still something quite "far away". According to a study about the motivation and implementation of traffic management strategies to reduce motor vehicle emissions across Canada [23], there is a misalignment between scientific data (which points to strong evidence of the benefits of LEZs for car-reducing emissions) and existing strategies, since, few cities or regions are proposing or even considering the idea of implementing an LEZ.

There are 22 different strategies in place to reduce motor vehicle emissions. While many of these strategies are in place to improve safety by reducing collisions and fatalities, alleviating traffic congestion, and reducing travel time, the main environmentally motivated measures are ride-share programs, improving public transit, and creating better facilities for pedestrians and cyclists.

The same study found that the governance model for transportation in Canada is not conducive to implementing regional transportation projects with environmental objectives, also noted "weakened regional visions within most urban areas" and "clashes between municipal and provincial visions", both of which can hinder the implementation of ambitious traffic management strategies such as road pricing and LEZs. Also, there appears to be significant concern about the acceptability and public acceptance of measures such as LEZs, mainly in a country with a large territory and intense car use.

In the USA, the country's first pilot LEZ ran through December 2022. It was a zero-emission delivery zone in a district of Los Angeles, and it specifically targets last-mile delivery vehicles whose presence has increased dramatically since the beginning of the COVID-19 pandemic, with an influx of food deliveries and online orders being made. The pilot incentivized clean, electric delivery vehicles by offering priority curb space in a monitored one-square-mile test zone in Downton Santa Monica, where any zero-emission

vehicle was eligible to park for 10 min to make a delivery or pick-up [59]. No other LEZ project or LEZ pilot project in the country is known.

4.4.3. Southeast Asia (Indonesia and Malaysia)

Among the 36 selected articles about the population's perception of LEZs, only two were located outside Europe. They are about Jakarta (Indonesia) and Petaling Jaya (Malaysia), both cities in Southeast Asia.

The context of Asia is quite different from the global North. According to the Asian Development Bank [60], in 2019, Asia had about half of the global population, but it only had about one-third of the global road supply and heavy rail infrastructure and about one-third of transport demand in passenger and freight activity. Also, 75% of urban residents in Asia lack efficient public transport, which means that the transport sector will continue to grow over the next few years, which is in line with the region's development. This is an additional challenge but also an opportunity to develop a low-emission urban transport infrastructure.

Despite this, among the 40 most polluted cities on the planet, 37 are in Southeast Asia: a mix of natural reasons (weather conditions) and human-caused ones. In 2019, Jakarta was one of the five most air-polluted cities. The main contributor was the transport sector [35]. Every day, Jakarta receives an influx of 10 million commuters from satellite cities, doubling its population and the number of vehicles traveling on its roads. Among these 20 million motorized vehicles, around 13 million were motorcycles [61]. To tackle pollution, the government implemented a series of strategies such as the development of public transport, the adoption of congestion charges, monitoring of vehicle emissions, and an LEZ (0.12 km^2). This small LEZ was established in the Kota Tua tourist area. An odd–even restrictive driving policy has also been implemented on many roads around the area, to support the LEZ. Now they intend to expand the LEZ area to maximize its impact on air quality and, consequently, in citizens well-being.

According to Rizik et al. [35], the infrastructure for walking and cycling in Jakarta is a concern for people. Unlike developed countries, which already have good infrastructure quality in supporting activities in LEZ areas, the Kota Tua LEZ was implemented in a small area with low-quality pedestrian infrastructure. While the Jakarta government has continued to improve this infrastructure, there appears to be a concern about the scale of the LEZ, which might not be positively influencing greater health, but only improving local air pollution.

Malaysia has experienced rapid urbanization, which resulted in a decrease in urban air quality. From 2015 to 2019, Malaysia's population grew by 1.4 million, while the number of registered vehicles increased by 3.7 million. Also, the number of stage buses decrease by 6% [62], reflecting a reduction in public transportation. Among the three main sources of air pollution, the transport sector responds to 87,8% of carbon emissions, mostly from mobile sources [36].

The city of Petaling Jaya is a leading development center and Klang Valley's central hub, an urban conurbation containing one-third of Malaysia's population. The city is strategically connected with other cities in the Klang Valley, resulting in high rates of congestion during peak hours and a high level of road traffic (>300,000 vehicles) in just 16 h.

Intending to improve air quality and, bearing in mind that comprehensive data on pollution emissions for Malaysian cities are scarce, a study ascertained residents' attitudes toward air pollution, their preferences for urban air quality improvement options, such as LEZs, carbon taxes, electric buses, carpooling campaigns, and programs to encourage residents to plant trees around their houses. The study's findings indicate that residents are willing to contribute and collaborate with the government to improve the air quality of PJ. Among the options, findings indicated a preference for a funding increase for carpooling campaigns and indoor planting programs, the conversion of four major congested streets to LEZs, and the introduction of electric buses [36].

4.5. LEZ Implementation: Issues, Actions, and Suggested Approaches

Many studies [25,32,36,43,49] indicate that populations, in general, have a positive attitude towards the need to tackle urban environmental pollution and support the implementation of LEZs. However, as stated by Oltra et al. [29], although certain interventions to reduce urban pollution are initially more accepted than others, it is possible to improve (as well as to worsen) the acceptability of these measures through their design and communication.

Based on the information available in the 36 articles studied, the main issues faced by cities in the acceptability and acceptance of LEZs were identified, as well as some of the mitigating measures implemented and suggested approaches presented by the authors to promote better acceptability and subsequent acceptance of LEZs.

4.5.1. Social Injustice (Issue)

Charleux [56] suggests that the implementation of an LEZ can be a source of social injustice, as this type of measure has a more significant impact on the cost of living of the less favored, hindering or even impeding their circulation, as they will most likely not be able to afford a less polluting vehicle. De Vril and Vanoutrive [34] indicate that Antwerp LEZ residents who no longer have a car indicate difficulties visiting others and no longer expect friends and relatives from outside the LEZ to visit them, the opposite of what was reported by official communication before LEZ introduction. Some authors [32,38] also highlight clear differences in how different socio-economic groups felt about air quality and LEZs. In the case of Bradford (UK), data obtained by Mebrahtu et al. [32] point to the fact that poorer families and immigrant families from countries with greater air pollution give less support to LEZs and less importance to air quality. However, after a more in-depth analysis, the authors realized that many of these families are drivers of taxis, vans, and lorries, whose businesses will be financially affected by the LEZ, and that for many families, other community issues such as fly-tipping, smells and vermin were more important issues to tackle. The study conducted by Rashid et al. [45] also supports this same idea.

4.5.2. LEZ Support Package (Action/Approach)

Several authors [25,29,32,38] highlight that implementing a set of measures that support and help mitigate the disruptions caused by the implementation of an LEZ has a significant impact, both on the acceptability and acceptance of the LEZ. This "support package" must be tailored to the characteristics of the city, the impacted area, the impacted stakeholders (residents, commuters, traders), and less favored groups. Ideally, this set of measures should be designed together with the population.

Among the most cited measures [29,38] are subsidy or free public transport (temporary or not), granting of exceptions (temporary or not), improvements in the supply of public transport and the connection between modals, providing financial support to less polluting vehicle acquisition, promote mobility share approaches, disclosure of the allocation of revenues raised by LEZ policy (e.g., improving local public transport or benefiting low-income people).

Based on the experience of the Rotterdam LEZ, Attia et al. [27] suggest that alternative sustainable modes of transport must be provided before restricting passenger cars from entering the LEZ for cities to absorb the transition and promote behavior change.

4.5.3. Phased Implementation (Action/Approach)

Case studies such as the LEZ of Madrid, London [46,54], Rotterdam [27], Jakarta [35], and Lisbon show the importance of introducing restrictions in a phased manner. The phases may be related either to the scope of the LEZ (increasing size or quantity of LEZs implemented over time), to the type of restricted vehicles (heavy vehicles, private diesel vehicles), or even to the period of operation (seasonal, weekends, business days). It is essential that the speed of implementation is appropriate to the capacity of the population

(residents, retailers, and commuters) and the city (by enabling quality transport alternatives) to adjust to the new model.

An interesting and perhaps unique case in Europe is the Berlin LEZ [55], where to adapt the implementation of the new measure to the particularities of citizens and companies, a large number of temporary exceptions were created, granted on a case-by-case basis, among them, vehicles belonging to a firm "whose survival is threatened by the scale of the investment required". It is important to note that despite temporarily allowing the entry of these vehicles, there was a charge for exemption. After 2 years of LEZ, no more exemptions were provided.

4.5.4. Political Issue and Contradictory Views of LEZ Efficacy (Issue)

According to Tarriño-Ortiz et al. [25], decision-makers should avoid implementing LEZs during an election period or using LEZs as a banner for their political project so the acceptability of the measure is not conditional to political-partisan issues. In the case of Madrid, LEZ acceptability was strongly related to political ideology once the implementation of Madrid Central LEZ was at the hotspot of the political debate in the region during 2018, generating confrontation among political parties. Furthermore, authors [25,29] suggest that public authorities should work to provide better information to the community based on quantitative research studies that demonstrate its impact on aspects such as air pollution, modal change, and economic and social impacts.

This type of information is also very important in tackling contradictory views about the potential effectiveness of LEZs, such as those observed in opinion surveys [32].

4.5.5. Psychological Factors (Issue)

Player et al. [33] advocate that the acceptability of LEZs is impacted by psychological factors, such as environmental moral obligation, perceptions of LEZ stringency, and environmental identity, as well as socio-demographic and travel-related factors, such as having dependent children and distance lived from the LEZ, and that this must be taken into account when defining the LEZ model to be adopted, as well as in the package of measures to support the LEZ.

4.5.6. Participation and Involvement of Stakeholders (Approach)

The authors agree that the population's participation and involvement in the elaboration of the measures introduced in the LEZ have a great impact on the acceptability and acceptance of the measure and should be valued.

Versigghel [63] states that for the long-term success of LEZ schemes, it is crucial that the population understands the scheme and its objectives so that issues of unequal distribution of benefits and burdens are not raised throughout the process. Also, regarding the space for discussion, participation should be proportional to the type of impact and focused on the groups that will be most impacted (e.g., residents, delivery companies, retailers). That is, greater impacts or more radical schemes should be reported more and discussed more than lighter implementations. Rashid et al. [43] suggest that multiple methods are used to engage with rarely heard populations and disadvantaged groups that may be adversely affected by proposals, including in-depth interviews, focus groups, surveys, and consultation events.

The study by Oltra et al. [41] concluded that emphasizing the positive impacts of the LEZ on the citizens' quality of life may have more positive impacts on acceptance than highlighting their effectiveness in reducing air pollution. Also, the legitimacy of the process of implementation of the LEZ, as well as the emotions associated with this instrument, are relevant factors in acceptance. For this reason, a positive engagement with residents may contribute to acceptance and support for the LEZ.

As stated by Attia et al. [27], from the start, clear reasons, a consistent strategy, a comprehensive package, and a long-term vision must be provided to the population so as not to create misunderstandings and unnecessary noise. Additionally, a good communica-

tion and participation plan is essential to avoid cases such as Edinburgh and Manchester (UK), where the population rejected the implemented projects, which resulted in the costly redesign of both cities' LEZs [33].

4.5.7. Behavior Changes and Indicators (Action/Approach)

The main objective of introducing an LEZ is to cause the population to change their behavior by adopting more sustainable mobility, which permits the city to have a good environmental quality while allowing people to move around easily across the territory.

Studies such as those by Ding et al. [28] about the demand for bicycle rentals after the implementation of London's ULEZ and by Moral-Carcedo [26] analyze how traffic intensity has been affected in both the Madrid restricted area and in other zones of the city, can be understood as indicators of behavioral change.

In the first case, in addition to an increase in bicycle rental demand inside London's ULEZ, the authors suggest that optimal bike allocation strategies should be implemented to improve the level of service of the bike-sharing system. Engineering measures such as cycle lanes, physical separations or barriers, and signalized crosswalks should be introduced to maintain the good results obtained so far.

In the second case, Moral-Carcedo [26] observed that while traffic in the Madrid Central LEZ has decreased, it has increased in these bordering areas. If the restrictions were fully effective in discouraging the use of private vehicles, a reduction in traffic should be perceivable in the entire access route to Central Madrid taken by non-residents using private cars.

As suggested by Attia et al. [27], to support LEZs and their related future decision-making, continuous monitoring and consistent evaluation regarding each specific measure and its linked accompanying package should be annually guaranteed.

4.5.8. Urban Freight Transport and Retail Activity (Issue)

Urban freight transport companies and traditional stores in the LEZ area are some of the stakeholder groups that tend to be greatly impacted by the LEZ, and for which adaptation measures need to be designed according to the context of each city.

In a study on the impact of LEZs on the urban freight transport market in London and Berlin [55], the authors observed that despite a reduction in the number of companies in operation caused by LEZs, this reduction benefited the market by forcing stakeholders to find ways to promote more efficient activities. Additionally, it promoted a necessary modernization in a sector that is dysfunctional in many aspects: environmentally, because of the old vehicles used until now, and socially, because of the large number of small companies that have difficulty maintaining a sufficient level of business activity without breaking the freight sector's labor laws and safety standards.

In a study about the impacts on conventional in-store retail activities in Madrid [25,30], the authors found that 68% of Madrid residents were in favor of LEZs as they have good public transport alternatives and a pedestrianization scheme to travel to the city center. Retailers appear to oppose the measure to a greater extent, as only 24.5% signaled a positive opinion. The difference in acceptance by residents and retailers may bias the impact on retail activity. However, residents can feel more comfortable enjoying the city center and shopping as LEZs improve air quality and the livable conditions of the area. From the retailers' point of view, traditional stores tend to have regular customers, who usually arrive in a pre-defined manner; therefore, restrictive policies can significantly alter their routines. Newer stores take advantage of and benefit from LEZs, as they can adapt more easily and attract new customers, such as tourists and young people, who are less dependent on private vehicles.

4.6. Review Study Limitations

It is important to note the limitations of the study during the review process. First, only English-language scientific publications from two specific databases (Scopus and WoS)

were considered in this review. Consequently, articles published in different languages, in different scientific repositories, or different formats, such as theses, were not assessed. Second, it is possible that other relevant research was not included in the analysis because of the search criteria outlined in the methodology.

5. Conclusions

The growing migration from rural areas to cities, the greater need for mobility, and car-centric mobility solutions have resulted in environmental urban quality degradation, affecting people's health, mental and physical well-being, and the city's economy and attractiveness, as well as harming urban ecosystems.

Due to better knowledge of the potential damage that air pollution can cause, policymakers worldwide are investigating which policies can help reduce local emissions in these areas. LEZs are one of the most widely adopted measures. Despite that, few articles evaluate the public acceptability and acceptance of LEZ implementation.

Using WoS and Scopus research databases, this study found 540 documents about LEZs, among which only 36 papers address public acceptability and acceptance of LEZs, highlighting the gap in studies on this topic. The objective of this article was to identify the main issues faced by cities, the main actions used to overcome them, and the author's suggestions regarding the cases studied. For this reason, a bibliometric analysis was conducted to determine important data. Also, articles were classified according to their approach to urban environmental quality, public perception scope, data collection method, and geographic location.

LEZs are traditionally focused on reducing atmospheric pollution, which was evidenced by the finding that among the articles analyzed, only 6% of them contained the term "noise". In contrast, the term "biodiversity" did not appear in any article. Despite this, the implementation of measures such as LEZs results in a noise reduction (either by reducing the number of vehicles or by the use of electric vehicles or vehicles with newer technology) and the preservation of urban biodiversity. Having said that, one has to wonder if, when talking about LEZs, should a reduction in noise emissions not also be considered as one of the objectives of LEZ implementation? In articles such as Jiménez-Espada et al. [16] and Kowalska [38], surveys carried out among the population show that noise reduction is one of the expected benefits of implementing LEZs. A broader approach to LEZs could bring even more significant gains in terms of urban environmental quality.

When evaluating studies on acceptability and acceptance, it is observed that only 8% of them contemplated both stages. To achieve the long-term success of the LEZ, it is essential that LEZs are evaluated not only before (acceptability) and immediately after implementation (acceptance) but that this process continues to be evaluated periodically to ensure that the project moves in the right direction towards a change in mobility behavior and that any adjustments, whenever necessary, are made, taking into account that the characteristics of cities and their populations change over time. Behavior change indicator studies such as [26,31] are good suggestions.

Regarding the data collection method, 67% of studies opted for surveys, which usually end up focusing on specific population groups. This may be a result of the need to limit it to those who have agreed to respond to surveys, which does not always reflect the reality of acceptability and acceptance of the different groups that make up that society and can lead to underestimated or overestimated conclusions. As a suggestion, a mix of different data collection methods can better capture the public perception. Also, data from sensors, be they traffic, smartphones, and other forms of data capture, can be useful to understand not only what people say (respond to surveys) but, in fact, their behaviors.

It was found that most of the articles are about European LEZs, except for two articles about LEZs in Asia (Malaysia and Indonesia). Of the 36 papers, 28% are about LEZs in the United Kingdom and 25% in Spain. While in Spain, 78% of articles refer to the Madrid LEZ, in the United Kingdom, studies are geographically diversified. In terms of urban

environmental quality approaches such as LEZs, the gap between countries in the Global North is evident.

Although studies generally indicate a good perception of LEZs, they also point to the fact that people tend to have a better perception of LEZs when associated with other behavioral change policies (here stated as "LEZ Support Package") and help to prevent that issues of unequal distribution of benefits and burdens are not raised throughout the process.

It is important to focus that the mitigating measures and suggestions highlighted by the authors are not a guarantee of acceptability and/or acceptance. Each city needs to analyze its issues and particularities to shape the best model and pace of the LEZ to be implemented. The successful model for one city will not necessarily work in another since the specificities, such as territory, culture, infrastructure, etc., will have an important impact on the success of the measure. LEZs are measures that need to be shaped by several hands, including the various stakeholders.

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