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Perspectives of Development of Low Emission Zones in Poland: A Short Review

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Introduction of low emission zones (LEZs) in many cities is supposed to mitigate negative externalities from urban transportation, such as noise and GHG emissions. LEZ is present in most of Western European countries, but in Eastern and Central Europe they are rare, even though in this part of Europe the air quality norms in the cities are very often exceeded. The experience from many countries proves that introduction of LEZ should be preceded with the examination of social acceptance to forecast and overcome the potential barriers of adoption to new rules and regulations. It is especially important in country such as Poland, where LEZs are going to be introduced in the near future. Hence, this article aims to review the factors responsible for social acceptance of LEZ and to discuss the prospects of establishing LEZ in Poland in the light of the experiences of other countries, urban and transport challenges in Polish cities, and legislative, economic, and social aspects. The results of the study are presented by means of SWOT analysis, showing that well thought-out solutions and the gradual introduction of restrictions in car traffic can have a positive impact on the level of social acceptance and behavioral change. Measuring social preferences and opinions before the establishment of LEZ could help investigate the relation between the level of restrictions and behavioral adoption of the residents and car users. It is also recommended to take a lesson from the zones already existing in other cities and to follow the solutions that have occurred to meet the expectations of the society while leading to lower GHG emissions and higher standard of living.

Keywords: sustainable transport, urban mobility, low emission zone (LEZ), social acceptance, electric vehicles, SWOT analysis, review

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INTRODUCTION

Transport is a major source of greenhouse gases and local air pollutants. The health, economic, and social costs of local air pollution are significant, ranging from reduced life expectancy and increased infant mortality to far-reaching economic consequences such as job losses or reduced consumer spending (Poulhès and Proulhac, 2021; Börjesson et al., 2021). The European low emission mobility strategy emphasizes the need to decarbonize the transport sector and to reduce emissions in this sector, especially in urban areas (COM, 2016).

Mechanisms to support the development of electromobility, micromobility, and carsharing involving, for example, layoffs from road taxes, registration taxes, financial benefits, and free parking in cities are used in most European Union countries, such as Germany, France, Italy,

Sweden, or Spain. In most of those countries also another measures—called low emission zones (LEZ) were taken to limit the negative impact of road air pollution in urban areas (Bernardo et al., 2021). LEZ are the geographical areas where the most polluting vehicles are regulated. This usually means that vehicles with higher emissions cannot enter the area. In some low emission zones, more polluting vehicles have to pay a higher toll when entering the zone.

LEZs have been well received in European countries primarily because these regulations are not too restrictive for citizens and most of them have been divided into stages, gradually eliminating further types of vehicles that will be prohibited from moving around the zone. Surprisingly, there are no LEZ in Central and Eastern European (CEE) cities, even if the quality of air in this region is often much below the accepted norms according to the World Air Quality Index (WAQI, 2022) or IQ Air (IQ Air, 2022).

Recently, Poland, one of the largest countries in CEE, has also decided to introduce LEZ in most polluted municipalities, regardless of the number of inhabitants, and introduce special markings for vehicles authorized to move within the zones. Although the final concept of LEZ and its legislative regulation does not meet all of the social expectations, the first important step has been already made.

The literature analysis indicates that smooth development of LEZ and its broader acceptance by the citizens is a gradual process and a lot of attention should be paid to wisely plan the location of the zone and the rules governing it (Morton et al., 2021; Bernardo et al., 2021). Therefore, the aim of this study is to discuss the perspectives of LEZ development in Poland, an example of the country from Central Europe, which has less experience in energy transition than Western European countries. At the same time, Poland struggles with low air quality in many cities and municipalities, due to intensive road traffic and coal burning in the household furnaces (Woźniak et al., 2020; Lis and Szymanowski, 2022). Knowing that apart from regulations and technical issues, social awareness and acceptance are needed for smooth diffusion of LEZ, and this article provides a review of factors responsible for social acceptance of LEZ. Furthermore, in order to understand and describe the current situation of LEZ in Poland, a SWOT analysis of strengths, weaknesses, opportunities, and threats is conducted.

The structure of the article is as follows. First, the article discusses the role of LEZ in sustainable transportation and provides a comparison between some zones in chosen Western European countries. Then, a current stage of implementation of LEZ in Poland, together with the analysis of social and economic factors is given. Finally, SWOT analysis summarizes the findings and leads to some conclusions and recommendations.

LOW EMISSION ZONES AS A PART OF THE SUSTAINABLE TRANSPORTATION AND URBAN MOBILITY

Currently, even 80% of all wealth generated in the world comes from the cities, which attract millions of people every year in search of better conditions for living. In 2020, even 2.59 billion people lived in metropolises, which is equivalent to one-third of the global population. This is a growing trend, and in 2050 even more than 60% of population is expected to live in urban areas (for more details see: https://unhabitat.org/global-state-of-metropolis-2020-%E2%80%93-population-data-booklet). That is why lack of planning in terms of cities' development, infrastructure, and transportation is very costly for individuals, governments, and the planet. Cities consume two-thirds of global energy and are responsible for over 80% of greenhouse gas emissions (Hoornweg et al., 2020). It causes the urgent need to make cities more sustainable and smart (Obringer and Nateghi, 2021; Song et al., 2022).

Sustainable and smart transportation with urban mobility include among others improvement of road safety, increase of the efficiency of transport systems, and encouragement for the citizens to switch from cars to more sustainable modes such as walking, cycling, or public transport (Tarriño-Ortiz, et al., 2022). Sustainable transportation can be examined by its positive and negative effects on the environment and climate change, local air pollution and noise, public health, congestion, economic growth, or social inclusion (Pridmore and Miola, 2011). At the same time many authors emphasize the social dimension of transport sustainability (Eriksson et al., 2008; Bristow et al., 2010; Sfendonis et al., 2017; Oltra et al., 2021; Tarriño-Ortiz et al., 2021). There is also a wide range of research examining various aspects of sustainable urban mobility (SUM), ranging from SUM planning (Okraszewska et al., 2018), social impact of SUM (Al-Thawadi et al., 2021), stakeholders' opinions about SUM (Foltýnová et al., 2020), role of autonomous vehicles (Acheampong et al., 2021; Golbabaei et al., 2021), to various micromobility issues (Abduljabbar et al., 2021; Kopplin et al., 2021), or the effectiveness of transport management policies on the air protection (Morfeld et al., 2014).

Acceptability of sustainable transport policies may conflict with individual interests, especially when individuals are asked to significantly adapt their lifestyles and transport behavior that may impact their comfort of living or lead to financial cost (Pridmore and Miola, 2011). The conflict between general policies aiming to reduce GHG emissions in the urban areas, such as car free days, car free roads, or peak-hour driving restrictions, and individual interests and comfort of urban mobility can be discussed on the example of low emission zones (LEZs). LEZs are areas where the most polluting vehicles are regulated or even forbidden. Usually it means that vehicles with higher emissions cannot enter the area or have to pay more if they enter the low emission zone. The operation of certain vehicles differs during specified times (i.e., during peak-hours or at the weekends). The role of LEZ is to mitigate congestion and environmental consequences of urban transport, by combining congestion charges and environmental restrictions. Their major objective is to improve health of residents by reducing fine dust PM10 and PM2.5 as well as nitrogen dioxide, NO_2, emissions by forbidding the entry of the most polluting vehicles (Börjesson et al., 2021; Morfeld et al., 2014). In most of the LEZs around the world, the restriction of entry is combined with a charge for admission and/or a penalty for access without permission. In total, it leads to the reduction of

TABLE 1 | Comparison of low emission zones in chosen European cities*.

City	Brussels (Belgium)	London (United Kingdom)	Milan (Italy)	Oxford (United Kingdom)	Paris (France)	Rome (Italy)	Ruhrgebiet (Germany)	Wien (Austria)
Area	161 km^2	Most of London	71% of Milan	Some streets in the city center	All Paris	5 km^2	820 km^2	415 km^2
Rules	Pay to enter or meet standards	Pay to enter or meet standards	Congestion and parking charges and access restriction	No possibility to enter if conditions are not fulfilled	Pay to enter or meet standards	Congestion and parking charges and access restriction	Congestion charges, no possibility to pay for entry if the car does not fulfil the conditions	No possibility to enter if conditions are not fulfillled
Banned vehicles	< Euro 4 diesel and < Euro 2 petrol	< Euro 6 diesel < Euro 4 petrol	Passenger cars: < Euro 3 petrol < Euro 6 diesel	Buses with < Euro 5 diesel or petrol	< Euro 5 diesel or petrol	< Euro 2 and < Euro 3 diesel (green zone) < Euro 3 and Euro 4 diesel (railway ring, incl. residents)	< Euro 6 diesel and < Euro 4 petrol	Delivery vehicle and trucks < Euro 3
Marking of vehicles	Car plates	Car plates or vignette	Vignette	Car plates	Vignette (Crit'Air sticker)	Emission test sticker	Vignette	Vignette
Phased implementation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source: PSPA Report 2020, Kua, et al., 2020 and following webpages: Brussels: https://lez.brussels/mytax/#.
London: https://tfl.gov.uk/modes/driving/low emission-zone?intcmp=2261.
Milan: https://urbanaccessregulations.eu/countries-mainmenu-147/italy-mainmenu-81/milano-lez-area-b#car; Paris: https://urbanaccessregulations.eu/countries-mainmenu-147/france/paris.
Rome: https://urbanaccessregulations.eu/countries-mainmenu-147/italy-mainmenu-81/rome.
Wien: https://urbanaccessregulations.eu/countries-mainmenu-147/austria-mainmenu-78/wien-vienna

vehicle traffic and reduced GHG (Hoornweg et al., 2020). These policies may also lead to either increase of number of alternative fuel vehicles (AFV), such as battery electric vehicles (BEV) and fuel–cell hydrogen vehicles (FCHV) in the cities, as these cars are usually released from congestion charges (Tarriño-Ortiz et al., 2021; Peters et al., 2021; Lis and Szymanowski, 2022) or may discourage from purchasing cars at all (Gonzalez et al., 2021).

Many cities in Europe restrict the usage of cars in accordance with the current atmospheric pollution situation. Low emission zones that regulate the entry of a vehicle into the restricted area if the vehicle does not meet certain environmental criteria are gaining popularity, especially in Europe. Nowadays there are around 220 LEZs in Europe, in a total of 14 countries. Most zones were established in Italy (105) and Germany (58), Netherlands (13), Great Britain (9), Austria and Sweden (8 each), Denmark (4), France and Norway (3 each), and Spain and Belgium (2 each). Greece, Finland, and Portugal function one low emission zone in the capitals of these countries (PSPA (Polskie Stowarzyszenie Paliw Alternatywnych), 2019). So far there are no low emission zones in Eastern and Central European countries and the Balkans.

The restrictions differ among the LEZs. Some cities ban heavy goods vehicles, some restrict or charge according to the emission standard of every vehicle that wants to enter the zone. **Table 1** presents the comparison between LEZ in some of the Western European cities. It can be easily observed that even if there are some differences in the area, type of marking the vehicles, or the detailed way the zone operates, generally each zone aims to regulate the types of vehicles which may enter. Cities set rules regarding the entry to the zone and payment (e.g., everybody pays, even the residents of the zone or residents are released from the fee.). Most cities differentiate charges or access based on the emission levels (i.e., certain Euro emission standard). In some cities, such as London or Rome, the zones are divided into separate areas with restrictions rising the closer is the city center. There are also periods of time (e.g., from Monday to Friday, or specific peak-hours) when the entry to the LEZ is specifically charged.

In each of the mentioned LEZ, the requirements evolve within the time. For example, London introduced an ultralow emission zone (ULEZ) only in 2019, after 11 years of operation of the low emission zone. Stage implementation allowed residents to get used to it and to adopt their behaviors and habits to the new regulations. This path has been going on for a long time that other European metropolises are following—Oslo, Hamburg, Amsterdam, Paris, Brussels, Madrid, Helsinki, Copenhagen, and Athens. They introduce prohibitions for conventional cars, they limit transit traffic, and they invest in infrastructure electromobility, public transport, or carsharing. The restrictions regarding the vehicles able to move around the zone were increasing gradually. In the coming years, the rules may become more restrictive and finally only BEVs and FCHVs

will be allowed to access the LEZ, as those means of private transportation do not generate exhaust fumes.

SOCIAL ACCEPTANCE OF LEZ

Several studies have been conducted to establish the various effects of LEZ. In most cases, the literature highlights significant effects of LEZs on air quality (Morfeld et al., 2014; Poulhès and Proulhac, 2021) or focuses on predicting changes in daily life prompted by the implementation of LEZs and similar policy schemes (Bernardo et al., 2021; Oltra et al., 2021), but still not enough attention is paid to social acceptance and business interest. Innovative and often costly mobility policies introduced in modern cities can fail if not combined with initiatives to raise citizens' awareness and promote behavioral change. As Morton et al. (2021) emphasize, introduction of a policy which may lead to restrictions in the mobility of citizens by limiting their personal freedom. Introduction of LEZ is always connected with some pricing measures, as LEZ involve charging for the access to the area which historically was entered by the transport for free. That is why it is necessary to measure citizens' willingness to pay for entering the zone, which is strictly connected with their acceptance level.

Social acceptance is a key to the development of various innovative solutions in different fields of our lives. In case of LEZ, social acceptance has also a critical meaning as the creation of low emission zones directly influences various groups of stakeholders, such as residents of the zone, citizens of the city itself, suburbs and smaller, satellite cities in the neighborhood, willing to get to the zone, where usually socially important public offices, banks, schools, companies, or entertainment venues (e.g., restaurants) are located. Apart from these groups, also business owners, whose companies are located in the area of the zone get affected. Sometimes even tourists, visiting the city centers, experience the effects of zone's introduction. Lack of public acceptance, as well as governmental support has already prevented the introduction of LEZ in many cities (Hysing and Isaksson, 2015; Vigar et al., 2011). That is why Morton et al. (2021) emphasized the need of understanding what factors positively influence public opinions and hence acceptance. Lurkin et al. (2021) go even further and highlight that the impact of LEZ on air pollution depends significantly on the interaction between the severities of the operational rules of LEZ with the behavior adopted by road users. The lack of positive impact of LEZ on the air quality lies among others in the negative spillover associated with the undesired behaviors of road users who for example decide to take detours and drive around the forbidden area (Lurkin et al., 2021). In other words, the effectiveness of LEZ is strongly related to its social reception and its impact of citizens' decisions and behaviors.

LEZ as a Part of Transport Demand Management

Up-to-date, literature discusses public acceptability of transport policies through the prism of transport demand management (TDM), that is, governmental policies intended to modify mobility behaviors of the citizens (Xianlong et al., 2016; Gu et al., 2018; Barceló and Martínez-Díaz, 2022). Policies usually divide into supportive and coercive ones, whereas the former intend to encourage desirable practices, and the latter to hinder certain actions. To examples of coercive (so called push policies) belong: congestion charging, parking restrictions, or toll pricing. TDM policies have a long history and their effectiveness in terms of social and economic aspects, as well as, traffic safety has been widely examined (Jones and Lucas, 2012; Munford, 2017; Barceló and Martínez-Díaz, 2022).

Low emission zones can be perceived as a sort of coercive TDM, as they restrict the access for certain types of vehicles in the specific areas and/or points of the time. According to Morton et al.. (2021), two attributes of LEZ distinguish them from area-based TDM measures. First, the introduction of LEZ has a special social goal, which is the reduction of local air pollutants within a certain area (i.e., part of the city) rather than improving the operation of the general transport system. If this aim is fulfilled, LEZ contribute to the social welfare by improving the conditions of living. Second, the financial impact of LEZ on an individual car owner depends strictly on the emission level of a given car rather than applying a set charge to a vehicle class (e.g., light-passenger vehicle, bulky vehicle, *etc.*). The evidence from the literature suggest that the aim of reducing air pollution rather than general increase of the efficiency of the transport system has greater chances to be socially accepted (Eliasson and Jonsson, 2011; Morton et al., 2021).

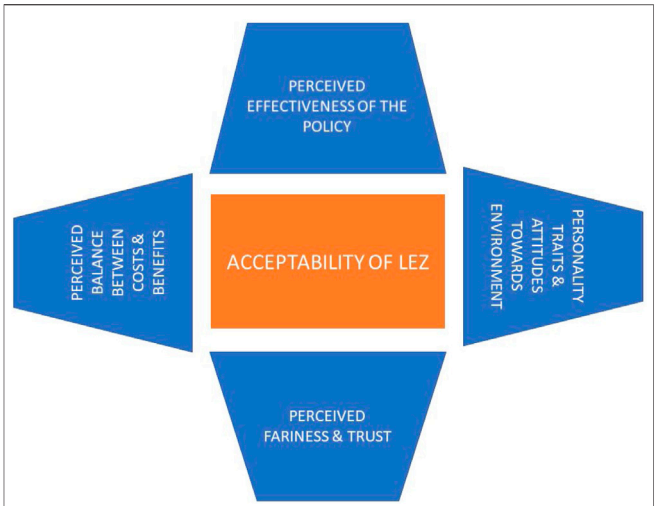

FIGURE 1 | Framework of factors affecting the acceptability of LEZ.

Acceptability of LEZ

Acceptability of various TDM tools has been broadly explored. Most of the findings are relevant also in case of acceptance of low emission zones. **Figure 1** presents the most significant factors influencing the level of acceptance and willingness to participate. Perceived effectiveness of policy belongs to one of the crucial indicators. This factor describes how the policy is evaluated by the

public. In case of LEZ, this leads to the statement whether introduction of LEZ has led to the significant increase in the air quality around the city. Then, perceived fairness connects with equity issues and trust that people have in the government and local authorities. This factor reveals how the policy is perceived by the audience—whether its costs and benefits are equally distributed among society members, especially those with low-income or belonging to ethnic minorities (Xianglong et al., 2016; Morton et al., 2021). The last factor inclines with the perception of the balance between costs and benefits of a given solution. The restriction of certain vehicles around LEZ due to the implementation of bans or additional charges is sometimes interpreted by the society as the limitations of their mobility options, which usually leads to negative opinions and reactions. Finally, personality traits, such as extraversion, agreeableness, and conscientiousness have occurred to be meaningful in the level of acceptance (Kim et al., 2014; Morton et al., 2021). Apart from that, also pro-environmental values and attitudes may influence the overall level of awareness, which is a fundamental factor of opinion formation and decision-making.

Morton et al. (2021) additionally found out that policy specific beliefs cover perceptions of the cost, procedural fairness, and efficacy of the scheme display a significant direct effect on the attitudes one has toward LEZ, while awareness of air quality issues holds a significant indirect effect. Those findings led to some practical applications, suggesting efforts it in creating a positive image of LEZ together with clear and transparent rules of its operation. Furthermore, the study of Martinez reveals that social acceptance is the result of a complex and dynamic process, based on four key components such as social influence, perceived usefulness, and sense of control and fairness (Martinez, 2019). The author suggests that there are several internal and external factors influencing the social acceptance. To internal factors belong among others demographic factors such as gender, age, education, place of living and working, income, and attitudinal factors such as trust, sensitivity to social influence, environmental attitudes, and travel-related habits. On the other hand, external factors include the scheme and area of LEZ with its price measures, as well as impact of information and education (Martinez, 2019).

Cost-Benefit Analysis of LEZ

LEZ are sometimes criticized by the public, especially due to the limitations of access and financial cost they cause. Situations vary greatly from one LEZ to another, with different perimeters and administrative boundaries because LEZs range from small downtown areas (e.g., 2 km^2 for LEZ in Ilsfeld, Germany) to much larger areas extending over large agglomerations (e.g., 1,500 km^2 for LEZ Greater London) (GUAPO Global Urban Air Pollution Observatory, 2020). The definition of the LEZ perimeter is crucial as most European cities have significant differences between the city center and its outskirts. City centers typically benefit from higher average household incomes, wider labor markets, and denser transport networks. The geographic scope of the LEZ will therefore influence not only the environmental and health effects of a policy but also its social impact—and thus the social acceptability of the policy itself (GUAPO Global Urban Air Pollution Observatory, 2020).

The establishment of low emission zones must have financial impact on the local government and on car owners. In case of local authorities the money collected from congestion charges, penalty fees or from distribution of vignettes is usually spent on the development of the transportation network in the given city. Many local governments invest the collected money in public communication means of transportation (i.e., new buses or trams) or/and in development of clean and safer roads for cyclists and pedestrians.

Although the establishment of LEZ should be preceded with the cost-benefit analysis (CBA), such an analysis is seldom performed. The literature mentions LEZ in Paris, London, and Antwerp for which CBA was conducted [eg., The London Low Emission Zone Feasibility Study, https://content.tfl.gov.uk/phase-2-feasibility-summary.pdf (accessed March 2022)]. The analysis included not only health benefit for population but also cost for owners of excluded vehicles and administrative costs or cost of change in trip duration.

In the work of Börjesson et al. (2021), a methodology for computing the social costs of an LEZ was developed. The authors compared social cost with benefits for LEZ in Stockholm. Their analysis has revealed that the social costs consist primarily of adaptation costs for drivers of banned cars, who either have to refrain from driving in the LEZ or trade their car for an LEZ-compliant one. Forecasted benefits of the LEZ consisted primarily of air quality improvements leading to health benefits and well much lower than the forecasted cost. The authors emphasize that the relative size of social benefits and costs are likely to vary between cities and LEZ designs. In some cities the health benefit might be larger than the social costs. The authors recommend to try and assess the costs and benefit before communicating a proposal of the LEZ policy to the public There is a risk of high cost incurred on car owners, particularly for owners of older cars that are often less affluent (Börjesson et al., 2021). Also Bernardo et al. (2021) emphasized that the effectiveness of LEZ cannot be taken for granted. LEZ are particularly effective in highly polluted cities, when they are applied to a wide area of the city, and/or when they are stringent in the type of restricted vehicles. Instead, LEZs are ineffective in mitigating congestion (Bernardo et al., 2021).

Also the rules of payments, used within particular zones differ. Bernardo et al. (2021) mention that an introduction of LEZs is often combined with traditional urban tolls. For instance, in 2019 London or in 2020 Stockholm implemented a special price-based LEZ in addition to the existing congestion toll. The Italian cities of Milan and Palermo have decided on a congestion charge combined with a LEZ, which means that all vehicles meeting the emission standards must pay a fixed daily charge during office hours (Bernardo et al., 2021). Having both policy measures available to local authorities gives them an accumulated flexibility to deal with both externalities simultaneously, as they can either change the level of tolls or the stringency of the LEZ, being a second option much better accepted by the population (Bernardo et al., 2021). In this situation, local authorities can better deal with the trade-off between

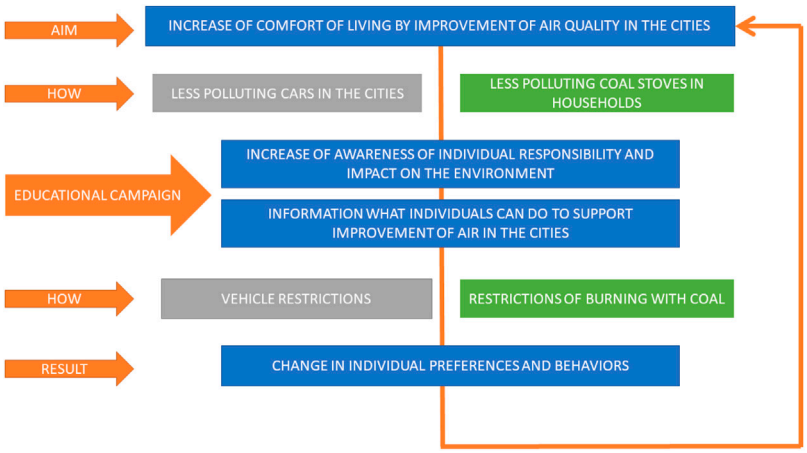

FIGURE 2 | Framework of actions needed to fight with urban air pollution.

effectiveness and acceptability when deciding on the best policy mix to implement.

Impact on Alternative Fuel Vehicles' Rollout

Last but not least, the introduction of LEZ has an impact on the development of alternative fuel vehicles (AFV) including electric, hydrogen fuel cells, or at least plug-in hybrids, both in public and private transportation, which may play a vital role in achieving carbon reduction (Kowalska-Pyzalska, et al., 2020). To some extent the acceptance of LEZ and willingness to pay for entering the zone can be combined with the interests and willingness to buy one of AFV. As Peters et al. (2021) indicate, the increase in alternative fuel vehicles registration shares due to the LEZ is found to be significant but fosters rather fossil fuel powered AFV, such as classic hybrid electric vehicles (HEV) and plug-in hybrid electric vehicles (PHEV) than zero-emission vehicles (eg, battery electric vehicles). This is reflected in the average CO_2 emissions of newly registered vehicles, which do not decrease significantly. The study of Peters et al. (2021) explains this phenomena by the impact of governmental support (i.e., subsidies) for non-electric AFV, treated as low emission vehicles, on the limited decarbonization of the vehicle fleet (Peters et al., 2021).

LEZ IN POLAND

Since many years various experts alarm that the transport emissions together with fumes from solid fuel boilers and stoves in household accounts for up to 80% air pollution in cities. The result is the smog and poor condition of the air. In Polish cities the standards are exceeded in over 70%. Every day it causes huge financial and health losses, and reduces life quality (Woźniak et al., 2020). **Figure 2** presents the framework of actions, which are needed to overcome these urban air pollution problems. In case of Poland, this aim can be achieved by limiting the pollution caused by transportation and household low-stack emissions (burning coal in home furnaces). As far as low-stack emissions are involved, there are several air protection programs in Poland (Adamczyk et al., 2017 for more details). Adamczyk et al., 2017 emphasize that protecting the air against pollutants from individual heat sources in countries such as Poland is very challenging, because of the dominance of coal as a primary source of energy, the use of old, low-efficiency boilers, and relatively long heating period. According to the authors the governmental support is necessary to persuade citizens to exchange the boilers into pro-environmental ones. Apart from that, GHG emissions from road transportation are a big issue. There are a number of strategies and directives guiding countries in transition from combustion engine vehicles into those fueled with electricity or hydrogen in order to limit harmful exhaust fumes (Kowalska-Pyzalska et al., 2020). Here, it must be emphasized however that the actual impact of electric vehicles on the emissions is ambitious. There is a broad literature examining the GHG emissions within the life cycle of BEV revealing that even if BEV enables zero exhaust fumes travel, in countries such as Poland, where the energy-mix includes mostly generation from fossil fuels (even 80% of electricity is produced from coal), the electric means of transportation cannot be treated fully as green ones (Tucki et al., 2019; Połom and Wiśniewski, 2021). There is also an unsolved problem of storage and utilization of batteries whose lifetime is relatively short (Kowalska-Pyzalska et al. (2020). Hence, a positive long-term impact of BEV on the sustainable urban mobility should be evaluated with caution. On the other hand site, electric vehicles limit the direct emissions of harmful fumes and do not generate noise, which is beneficial for the inhabitants of the cities. From this point of view their presence in the cities is reasonable and desired.

The diagram in **Figure 2** indicates that no matter which cause of poor urban air quality is taken into account, in both cases the educational effort is necessary. Education should lead to the raise of awareness of the problem—its causes and effects—as well as

measures to prevent and eliminate the existing pollution. Within the further analysis we will focus on the first way of increasing air quality in the cities, that is the decrease of the number of polluting cars in the cities. In order to understand the challenges that Poland face in this area, the short description of Polish transportation is provided.

Urban Transportation in Poland

Nowadays, over 20 million cars move on Polish roads. Every year over 1.5 million cars are registered. Not only the number of cars on Polish roads but also their age should be worrying. In 2019, about one million second-hand cars were brought to Poland. While Western Europe systematically gets rid of used, exploited, and not meeting the environmental standards vehicles, a considerable part of them is imported to a country such as Poland, where these cars are then used for many years after some superficial repairs. The average age of cars brought to Poland amounts to approximately 12 years. According to the statistics of the European Automobile Manufacturers' Association (ACEA) in 2018 only 30% of cars on Polish roads were 10-years-old or less and only one car out of ten was approximately. 4-years-old. According to the data of insurance companies, the average age of cars on Polish roads exceeds even 13 years! (PSPA (Polskie Stowarzyszenie Paliw Alternatywnych), 2019).

The report by Polish Smog Alert, Kraków (2020) informs that a car is a regular means of transport for 44% of inhabitants of Polish largest cities. It is only 3% less than the percentage of passengers using public transport daily. The research results show that a lack of direct connections to destination rank at the top of all barriers, making it difficult to give up on one's own car for the benefit of public transport (Polish Smog Alert, Kraków, 2020). That is why in many cities the decline of public transport to the benefit of private one is observed. The scope of public transport differs depending on the specificity of particular city transport market and the related functional area. In big cities a tendency to restore the urban public transport market position can be observed or at least slowdown of its decline. The share of travels by private cars is comparable to the cities in Western Europe, whereas the share of bicycle travels is still lower, although in many cities we can observe its significant growth rate (Wołek, 2018). At the same time Wołek (2018) emphasizes that in Poland we may observe the dynamic development of individual motorization. The number of private cars in Poland increased by almost 200% from 2003 to the 2016 (CSO, Local Data Bank, Warsaw, 2018). Mass motorization development on transport market in Poland has been supported by, among others, low parking fees, no charges for entering city center by car, significant number of available parking places, no emission-free zones, and investing EU resources firstly into developing infrastructure supporting private cars (Wołek, 2018). But now the priorities have changed and increasing attention is paid to sustainability of urban mobility and transportation.

Legislative Aspects of LEZ

The opportunity to create so called clean transport zones (i.e., accurate translation of the Polish name of LEZ) was given to the Polish cities by the Act on Electromobility and Alternative Fuels, which entered into force on February 2018. The initial concept assumed that such a zone can be established in communes with over 100,000 inhabitants. There are 39 such administrative units in Poland, but so far only Kraków and partly Łódź (due to the ELAB—the city of clean transport project) have decided to introduce clear transport zones; however, because of the low level of social acceptance these pilot projects have been suspended. According to the Polish Alternative Fuels Association (PSPA), which presented the report on clean air zones, the zone in Krakow was closed due to overly restrictive regulations. The access to the zone was restricted to only vehicles fully electric, hydrogen powered and natural gas. The problem was however, that there were not enough such cars in 2019. This must have resulted in the lack of social acceptance and aversion to establishing the zone.

In February 2021, the European Commission called on Poland to meet the requirements of the directive on air quality and cleaner air for Europe. It indicated that in agglomerations, such as Upper Silesia, Krakow, Warsaw, and Wroclaw, the level of nitrogen dioxide from road transport has been exceeded many times. In response the presidents of the largest Polish cities have formed a coalition for the development of LEZ. In the declaration issued with the Polish Alternative Fuels Association, officials wanted the regulations to be changed so that it is possible to flexibly adapt the rules in force in the zone to the needs of a given local government. They have made following recommendations to the government: 1) LEZ should be managed by local governments; 2) the area of LEZ should be gradually expanded and initially allow the movement of vehicles that are not listed in the law; 3) after some time has passed, only zero-emission cars—similar to Western European cities—would retain the right to enter. Taking into account social and economic conditions, the legislator should also allow conventional vehicles to move within the zone, which meet the relevant emission standards according to Euro classification, assuming the progressiveness of the zones and their gradual closing to combustion vehicles. Cities should also be able to create several zones with different criteria, taking into account local conditions, as well as the possibility of creating "zones within a zone," that is, places where more stringent requirements would apply. While the determination of the maximum rates of fees for entering the zone of a non-compliant vehicle should be left to the legislator, the entire rules for admitting such vehicles to the zone should be determined by the local government. The statutory regulation should also be supplemented with provisions ensuring that the establishment of the zone will take place in a manner ensuring the participation of residents of the area where the zone is to be designated.

Finally, the government has taken only part of the recommendations into account. The amendment to the act on electromobility and alternative fuels entered into force on 24 December 2021. As a result, the rules governing the establishment of clean transport zones (i.e., the accurate translation of the Polish name of LEZ) have changed. In the light of the new regulations each commune no matter, how many residents it has, may arrange LEZ as a method of fighting with urban air pollution.

This is a good step because the problem of emissions from transport is not the only problem for the largest cities and inner-city districts. At the same time there is no legal obligation to create LEZ even if the level of air pollution is high. The act on electromobility prohibits entry to the zone by vehicles other than electric, hydrogen powered, powered by natural gas, service vehicles, and vehicles excluded under a resolution of the commune council.

According to the act, there will be a single-sticker design for entry into the clean transport zone throughout Poland. This means that a person with a sticker issued for a specific clean transport zone on one's vehicle will in practice be able to freely enter any zone in Poland, regardless of the fact that the entry restrictions under the zones may be different. Experts believe that one model of the sticker will make it difficult to control the legitimacy of entry. This may lead to chaos and the inability to enforce the introduced restrictions—and, consequently, for zones to lose any role in improving air quality in cities.

In order for the zones to actually achieve the goal defined in the act, which is to improve the quality and reduce the negative impact on the environment and health of the inhabitants, first the oldest, most polluting vehicles should be eliminated from traffic and the gradual replacement of these most emitting vehicles with less emission ones should be encouraged. EURO 5 is the most commonly considered standard. Then, the entry of the vehicles with emissions above the designated threshold would be restricted. The problem is however that in Poland about 60–65% of cars do not meet this standard. That is why the design of the zone should include a special fee for the non-compliant cars at specific times during first years after the introduction of the zone. It would ease the adoption process to new rules and regulations.

Social Aspects and Opinions

Since more than 20 years the transport policy management in most big Polish cities has been dominated by declarations of the development of effective public transport and a simultaneous continuation of investments in individual car transport (Polish Smog Alert, Kraków, 2020). City and government administrations were aware of the increasing number of cars circulating on urban roads and its negative impact on collective and individual transports, even though the problems remained unsolved. Over the past few years, it can be seen that awareness of the environmental impact is awakening in Poles (see, ARC Market and Opinion and Responsible Business Forum, Consumers and the circular economy). It is particularly noticeable among residents of large cities (Szczuraszek and Chmielewski, 2020). Both city authorities and private companies are investing more and more in ecological means of transport, such as electric buses, city bikes or carsharing, and scooter-sharing (Zawieska and Pieriegud, 2018). But still a lot of problems remain including huge traffic jams in the largest cities and bad quality of the air due to exhaust fumes. Implementation of some transport management tools, including low emission zones, could be the cure.

The survey conducted in 2020 by Polish Smog Alert aimed to explore the most urgent issues of transport in largest Polish cities according to ordinary residents of these cities. The report reveals that most of the inhabitants of large Polish cities have negative experience with public transport. The report indicates that busy roads, lack of separate bus lanes or tram tracks create the same reality for both passengers of buses or trams and drivers of private cars, discouraging the use of public transport (Polish Smog Alert, Kraków, 2020). According to the survey, more than 70% of respondents find traffic jams to be the biggest problem related to transport, no matter whether it is individual or collective one. Second barrier most often mentioned by respondents were the lack of parking places downtown. Low frequency of circulation of public transport ranked next on the list of transport related problems in the cities. Inhabitants of the biggest cities pointed it as a problem twice as often as the limited connection network. The report concludes that the inhabitants expect persons in charge of public transport in big cities to make public transport means circulate more often, which will decrease the traffic and increase the speed of travelling. For people living outside city centers also the limited amount of park + ride areas has been also pointed among the urgent issues related to urban transport (Polish Smog Alert, Kraków, 2020).

Additionally, Polish Alternative Fuels Association (PSPA) who investigated attitudes toward the introduction of LEZ, found out that Poles are in favor of introducing clean transport zones in communes, but they prefer larger and less restrictive zones to smaller ones, which only electric, hydrogen, or natural gas cars can enter. In the opinion of Poles, in the first stage of implementing of LEZ, entry bans should be introduced mainly for the oldest and most emissive cars (PSPA (Polskie Stowarzyszenie Paliw Alternatywnych), 2019). The public report "City image library"—provided by the marketing agency AMS in 2016, revealed that as many as 77% of respondents have never encountered the term "smart city" or "smart city." In turn, only every third participant in the study agreed that his city is intelligent. The meaning of the concept is also interesting , which differs in the case of inhabitants of larger and smaller towns. For the first, smart city is primarily new technology, and for the second—"a city that improves the quality of life of residents, responding to their needs" (Hatalska and Kuzaka, 2016). Another study, from 2018, indicates that 10% of Poles associate the term "smart city," and among them as many as 40% identify it only with intelligent lighting (FIBARO newsroom). According to the experts of urban development, smart cities are the necessary future and direction of the urbanization, in order to achieve the aims of the fourth and fifth industrial revolution (Kowalska-Pyzalska, et al., 2020).

In the opinion of most Poles, the catalog of vehicles allowed to enter the zones should be expanded. They support the idea of creating closed zones (65%), but in the first stage their implementation, the entry ban should include mostly the oldest and most old cars emission. The average age of a car in Poland is 13 years. Already the requirement of higher Euro standards for diesels and gasoline vehicles would bring an improvement. Half of Poles have a bad opinion of the air condition in their city. The most frequently indicated (76%) benefit for residents resulting from the introduction of clean transport zones is cleaner air and the fight against smog. Over

TABLE 2 | SWOT analysis of LEZ in Poland.

Strengths	Weaknesses
S1. If the area of LEZ is large enough, then a positive impact on air quality is observed	W1. Lack of clear legislative framework guiding, which cars are allowed to enter the zone
S2. Proper design of LEZ encourages environmental means of transportation including: cycling, walking, car or bike-sharing, or usage of public means of transportation	W2. Not enough flexibility for the municipalities in arranging the regulations what may lead to an inefficient design of the zone and social resistance
S3. Introduction of LEZ increases the interest in BEV, PHEV, and FCHV vehicles	W3. There are still many old cars on the Polish roads, not meeting the standards of Euro norm
S4. Introduction of LEZ increases the quality of living in city centers due to limited traffic	W4. The network of charging stations is still not dense enough to encourage broader presence of BEVs
Opportunities	**Threats**
O1. Growing awareness of the negative impact of environmental pollution through excessive public transport in the city	T1. Unstable legislation, not taking into account suggestions from public consultations
O2. Growing sales of BEV in Poland among private car owners as well as an obligation to exchange the public car fleet into the low- or zero-emission one	T2. Danger of too rapid and too restrictive rules of entering the zone instead of the gradual process of LEZ introduction
O3. Advance in technology in case of BEVs, FCHV as well as conventional cars making them more efficient and environmentally friendly	T3. Preferences of Polish households indicating that Poles still prefer to buy conventional cars as a first-family car, and alternatively electric car as a second car to be used in the city
O4. Change in habits and fashion leading to broader usage of bikes and scooters in transportation especially among young and middle-aged inhabitants	T4. Danger of social opposition to creation of LEZ due to the barriers in transportation and limitation of personal freedom
O5. Engagement of local government units (cities and municipalities) and NGOs in creation of reasonable legislation	—

60% of the respondents indicated a reduction in traffic in the city center, and more than half—reduced noise (PSPA (Polskie Stowarzyszenie Paliw Alternatywnych), 2019).

The respondents did not agree, for example, with the entry ban to the zone for hybrids that are commonly sold in Poland (even 20 thousand per year). The majority of respondents (73.4%) believed that the clean transport zone in their city should cover a larger area and be less restrictive. More than 60% of respondents believe that electric vehicles should enter the clean transport zone, and 56% indicated plug-in electric vehicles (PHEV). More than half of the respondents would allow even hybrid HEV vehicles to enter the zone. Two out of three respondents believe that entry to a low emission zone should be limited gradually. The main indications for which local governments should allocate funds from fees for entering clean transport zones are the purchase of zero-emission buses for public transport (52%), infrastructure (46%), additional public transport connections (45%), and the construction of BEV charging points (40%). The majority of 68% of respondents believe that, in addition to emergency vehicles, residents should have access to the zone. More than half also indicated suppliers as the ones that should be allowed to access the zones (PSPA (Polskie Stowarzyszenie Paliw Alternatywnych), 2019).

DISCUSSION

In order to outline the insights for Poland, the SWOT analysis was chosen. SWOT analysis is a common tool to evaluate an innovative solution or business concept in terms of its strong and weak internal attributes as well as opportunities and threats in the macro-environment. **Table 2** includes SWOT analysis for establishment of LEZ in Polish cities. It summarizes the findings regarding the chances and barriers of creation of LEZ in Poland. Strengths of LEZ are inspired by the case studies from other countries, because Polish experience in this field is limited, whereas weaknesses are stimulated by the negative experience with two zones in Kraków and Łódź and current legal regulations. Opportunities and threats are proposed for Poland; however, they are relevant also for other countries.

The SWOT analysis shows there are a lot of opportunities for the right introduction of LEZ in Poland. But at the same time there are still many barriers that must be taken into account while designing the zone. Hence, well thought-out solutions and the gradual introduction of restrictions in car traffic can be a solution for Polish conditions. The decision-makers should remember that LEZ will not bring positive environmental results (i.e., cleaner air, less noise due to the intensive traffic) without social acceptance of the residents. That is why they should analyze carefully the design of the zone in terms of the vehicles allowed and restricted to enter, area of the zone and spread of the rules over the time. Measuring social preferences and opinions before the establishment of LEZ could help them investigate the relation between the level of restrictions and behavioral adoption of the residents and car users. It is also recommended to take a lesson from the zones already existing in other cities and to follow the solutions that have occurred to meet the expectations of the society while leading to lower GHG emissions and higher standard of living.

CONCLUSION

This article has summarized the current empirical and theoretical findings regarding the concept of low emission zones. Even though a lot of research has been already done regarding various aspects of LEZ, to the best of author's knowledge an

analysis from the point of view of the country, where from one side the level of GHG emissions due to the intensive traffic extend most of the standards, and from the second side there are no restrictions for the oldest, most polluted cars to enter any part of the city, has not been carried out yet.

The conducted analysis clearly indicates that LEZ can serve as a great tool to mitigate negative externalities of extensive urban transportation such as noise and GHG emissions, but only if they are properly designed and their introduction is socially accepted. Without social acceptance the behavioral change, which is necessary for better air quality and life condition for the inhabitants of the cities, will not be achieved. Another conclusion from the analysis is that to lower the level of pollution in the cities, low- or zero-emission cars must gradually replace a noticeable part of conventional cars. It is again connected with the desired behavioral change that can be encouraged by the governments who set the rules regarding the area where the most polluted cars are excluded, as well as who impose policies subsidizing the exchange of old, conventional cars into modern, low, or zero-emission ones both in private and public transportation. Finally, in countries, such as Poland, where even 80% of energy is generated from fossil fuels, the electric vehicles cannot be treated as fully pro-environmental ones. Of course, their usage do not cause direct emissions of harmful fumes, but still their carbon footprint during production and charging of the battery is substantial. Moreover, there is the unsolved problem of utilization of used batteries. Perhaps, encouraging people to choose public means of transportation, bikes, and scooters (both private and in sharing scheme) would bring more advantages to the sustainable urban mobility in the short- and long-term, rather than the development of restriction policies. But this is the topic for some future work.

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AK-P collected the data, analyzed and synthesized it, and drawn the conclusions. AK-P prepared the visualization of the results (Tables and Figures) and wrote the whole manuscript.

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