Analysing the distributional effects of low emission zones. A case study of the city of Barcelona.

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Abstract

This thesis is framed in the context of the urgent need for integrating social justice into sustainability policies, emphasising the concept of a "just transition" towards environmental harmony without compromising social fairness. An academic consensus on the interconnectedness of environmental policies and social justice is highlighted, despite existing gaps between aspirations and realities. Urban areas, due to their significant contribution to greenhouse gas emissions and vulnerability to climate change, are identified as crucial for implementing effective and equitable climate policies. Given the scarcity of empirical studies on integrating social justice principles into sustainability policies, especially regarding Low Emission Zones (LEZs) in urban settings, this work addresses the knowledge gap concerning the potential distributional effects of LEZ in the case of Barcelona (Catalonia, Spain). Although LEZ has benefits, it raises concerns about its potential negative impacts on low-income communities, such as unfair access and mobility restrictions and financial burdens, underscoring the need for a comprehensive examination of LEZ policies to ensure they advance both environmental goals and social justice

Employing an embedded single-case study analysis design, the methodology combines quantitative and qualitative research techniques, structured in three distinct phases. First, a statistical correlation analysis was conducted to examine the numerical relationships and trends between household income, the proportion of non-compliant cars, the quality of public transport, and the percentage reduction of non-compliant cars. Second, a qualitative survey was conducted to acquire qualitative data and insights from the population of the poorest and richest neighbourhoods in Barcelona. Finally, interviews with four experts were conducted to discuss and validate the results and information obtained.

The findings from both the statistical correlation analysis and qualitative surveys reveal that the LEZ policy in Barcelona does have some distributional effects that are disproportionally felt by lower-income households. The statistical correlation analysis shows how lower-income populations might feel the effects of the LEZ policy implementation more strongly, and the results show a higher proportion of non-compliant vehicles when the policy was established and a higher economic burden in replacing those vehicles. Moreover, the qualitative surveys reveal that lower-income groups face challenges in adapting to the policy, especially when they live in areas with poor public transport quality. Residents of the higher-income area exhibit greater awareness and adaptability to the LEZ requirements, while residents from the lower-income levels exhibit significant difficulties to adapt.

The findings, together with the collective insights from interviews with experts, advocate for a more equitable approach to LEZ implementation, stressing the importance of enhancing accessibility and reducing economic strain for the most affected. In conclusion, the findings of this thesis underscore the need for policies that are both environmentally effective and but also socially just, incorporating the perspectives of vulnerable populations in the policymaking process. The findings advocate for a more equitable approach to LEZ implementation, stressing the importance of enhancing accessibility and reducing economic strain for the most affected.

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Introduction and research design

1.1 Problem definition

Sustainability policies

In the quest for a sustainable future, there is a growing consensus within the scientific community that the path to environmental harmony must be just (Wang & Lo, 2021; Malloy & Aschcraft, 2020; Kinsly et.al, 2017). The concept of "just transition" has gained prominence in recent years, echoing the collective recognition that efforts to address environmental challenges cannot come at the cost of social justice and fairness (Stevis & Fellis, 2020; Bright & Buhmann, 2021; Wang & Lo, 2021). Yet, despite the growing acknowledgment of this issue, the journey towards reconciling sustainability and justice remains an ongoing challenge. While there have been significant strides in understanding the intricate connections between environmental policies and social justice, it is clear that the gap between aspiration and realisation has not fully been bridged (Shi et al., 2016; Bright & Buhmann, 2021; Anguelovski et al., 2023). This highlights the pressing need for a deeper exploration of the complexities involved in forging a truly just and sustainable future where the welfare of both the planet and its inhabitants is harmoniously upheld.

In the pursuit of a sustainable and just transition, urban landscapes emerge as a critical arena. With over half of the world's population residing in cities, responsible for three-quarters of global energy consumption and greenhouse gas emissions (Steel et al., 2015; Mi et al., 2019), the urban context is pivotal. The substantial contribution to greenhouse gas emissions and cities' vulnerability to climate change underscore the urgency for effective urban responses (Bulkeley & Betsill, 2013; Amorim-Maia et al., 2022). This has prompted global organisations to prioritise addressing climate challenges at the urban scale, fostering renewed efforts for mitigation and adaptation.

Local city governments worldwide are developing adaptation plans and implementing climate policies aimed at promoting sustainability and resilience (Bulkeley, 2021). However, there is limited knowledge regarding how the vulnerability of the urban poor is impacted by these plans and their execution (Anguelovski et al., 2016; Anguelovski et al., 2023). Critics contend that urban climate policies pay little attention to the realities of marginalised communities (Peck, et al. 2009), perpetuating inequalities and the marginalisation of vulnerable populations (McArdle, 2021; Amorim-Maia et al., 2022). Therefore, policymakers face a growing urgency to embrace intersectional policy frameworks that address inequalities holistically and build capacity for transformative, sustainable futures (McArdle, 2021; Amorim-Maia et al., 2022).

Transport policies

Transport policies are pivotal in urban climate mitigation, addressing the dominant role of automobiles in escalating emission levels globally (Pojani & Spead, 2015). Among these policies, Low Emission Zones (LEZ) are widely adopted for climate mitigation (Gonzalez et al., 2022). LEZ restricts high-polluting vehicles, aiming to curb emissions, especially in areas with elevated air pollution levels that pose health risks and exacerbate climate change impacts (Holman et al., 2015; Margaryan, 2021). Air pollution is a critical challenge for cities, causing over four million premature deaths annually (World Health Organization, 2022). The first LEZ, implemented in Stockholm in 1996, inspired subsequent adoption in cities worldwide, including London, Paris,

Berlin, Barcelona, Tokyo, etc. (Dablanc & Montenon, 2015; Oltra et al., 2021). In the wider scope of promoting social justice in sustainable urban transitions, it's crucial to recognise that, while LEZs show promise in reducing pollution, concerns have surfaced about potential unfair restrictions on geographical accessibility, shifts in mobility patterns, and disproportionate financial burdens on low-income groups, such as the need to purchase a newer vehicle or facing extended travel times to reach LEZ areas. A thorough examination of LEZ policies for their distributional effects is not only vital for achieving environmental goals but also critical for advancing social justice in cities (Rikzi et al., 2022; Verveek & Hincks, 2022).

1.2 Knowledge gap

As mentioned above, the recognition of social justice as a crucial element in achieving a sustainable society has gained importance in both academic discourse and policymaking in recent years. The argument is that examining equity and justice is crucial to grasping the nuances of climate politics and to making meaningful contributions towards achieving substantial, equitable, and lasting climate solutions for both current and future generations (Kinsly et al., 2017; Malloy & Ashcraft, 2020). However, while it is generally recognised that sustainable transitions must address both environmental concerns and their socio-economic implications, a knowledge gap on how to combine these two goals still exists, particularly in the realm of urban environmental policies (Wang & Lo, 2021). This section identifies the layers of this knowledge gap and emphasises the need for a more nuanced examination of the impact of sustainable urban policies, specifically LEZ, on social justice.

First, at its most general level, this thesis aims to contribute to the **existing insights on the matter of integrating social justice into the sustainability transition**. While the theoretical framework for incorporating social justice into sustainability transitions has been substantially developed in recent years (Malloy & Aschcraft, 2020; Steven & Felli, 2020; Huttunen et al., 2022), there remains a disparity between theoretical conceptualization and practical implementations. Few empirical studies have comprehensively examined how the principles of social justice are integrated into real-world sustainability initiatives, limiting the understanding of their actual impact on marginalised communities.

Secondly, and more specifically, this thesis addresses **the knowledge gap concerning the potential distributional effects of urban environmental policies**, which are integral to sustainability transitions. While urban environmental policies play an essential role, existing literature often lacks in-depth analyses of their social justice implications (Zachmann et al., 2018). Although some studies have explored the distributional effects of climate policies at national levels, such as carbon pricing and taxation-related policies (Bureau, 2011; Sterner, 2012; Mathur & Morris, 2014; Wang et al., 2016), they are limited and often yield ambiguous results (Ohlendorf et al., 2021). Moreover, studies focusing on the distributional effects of urban climate policies, such as those by Fitzgerald (2022) and Shi et al. (2016), are predominantly conceptual frameworks rather than empirical analyses of existing urban policies. This gap underscores the need for more empirical research to evaluate the distributional effects of environmental policies, particularly within urban areas. Such research is crucial for understanding whether urban climate policies exacerbate or alleviate existing social inequalities within urban communities. Thus, this thesis intends to contribute insights on how to bridge this

gap by conducting an empirical analysis of a real-world urban environmental policy, providing valuable insights into its social justice implications.

Finally, the main contribution this thesis aims to provide is **knowledge regarding the distributional effects of LEZ policies, specifically in the case of Barcelona**. LEZ represents a critical subset of urban environmental policies designed to mitigate the environmental impact of transportation. Despite their increasing adoption in cities worldwide, there is a notable dearth of research focusing on the social justice aspects of LEZ. Previous studies in this field have primarily concentrated on the environmental benefits of LEZ (Holman et al., 2015; Pestel & Wozny, 2021), with limited attention to their broader societal implications. Understanding how LEZs affect different demographic and socioeconomic groups, including their access to transportation, economic well-being, and overall quality of life, remains an underexplored area.

This study will focus on the city of Barcelona, Catalonia, Spain; which implemented the LEZs policy in 2020. It will examine the distributional effects of Barcelona's LEZ policy. By focusing on Barcelona and its metropolitan area (MAB), this study can provide insights into the specific challenges and opportunities that arise when implementing LEZ policies in urban areas with unique socioeconomic and environmental contexts.

1.3 Research objectives and research questions

This thesis aims to contribute insights into ways in which more just urban transitions can be promoted by examining the distributional effects of the LEZ policy in Barcelona. Specifically, it involves a comprehensive analysis of the mobility and economic impacts of the LEZ policy on diverse income groups within the MAB. This thesis is dedicated to assessing whether the distributional effects align with principles of social justice or contribute to disparities, thereby contributing valuable insights to the discourse on sustainable and just urban development.

In order to achieve the objective of this research, the following research question has been formulated:

What are the distributional effects of Barcelona's LEZ policy, and what lessons can be derived from this case in order to adopt better practises for the implementation of the LEZ policies?

Sub-question 1: *Which potential distributional effects of LEZ policies can be derived from previous research regarding LEZ policies, other climate-related transport policies, and other relevant literature?*

Sub-question 2: *How can insights from existing literature on LEZ, climate and transport policies, and other relevant literature be integrated to develop an analytical framework for evaluating the distributional effects of LEZ policies?*

Sub-question 3: *What are the distributional effects of Barcelona's LEZ policy based on the analytical framework developed in sub-question 2, and how do these effects vary across different demographic and socioeconomic groups within the city?*

Sub-question 4: *How do insights from professionals and experts in the field of mobility enhance and contextualise the findings obtained in sub-question 3?*

Sub-question 5: *What are the implications of these findings for possible improvements to the LEZ policy in Barcelona to reduce distributional effects?*

1.4 Research Framework

This study was conducted in four main phases, and Figure 1 shows the processes used to address the main research question and sub-questions. To understand the potential distributional effects of LEZ policies, a literature review was carried out in Phase 1. Phase 2 consisted of the development of an assessment framework based on existing literature to understand how the benefits and burdens of LEZ are distributed across various groups with different socio-economic statuses. Phase 3 started once the assessment framework was created. In this stage, a case study was carried out to examine the distributional consequences of the LEZ policy in Barcelona, applying the assessment framework. Finally, phase 4 of the study consisted of a validation step discussing the results with mobility experts and in relation to the existing literature.

Afterwards, recommendations for an equitable implementation of LEZ in Barcelona were made based on the findings.

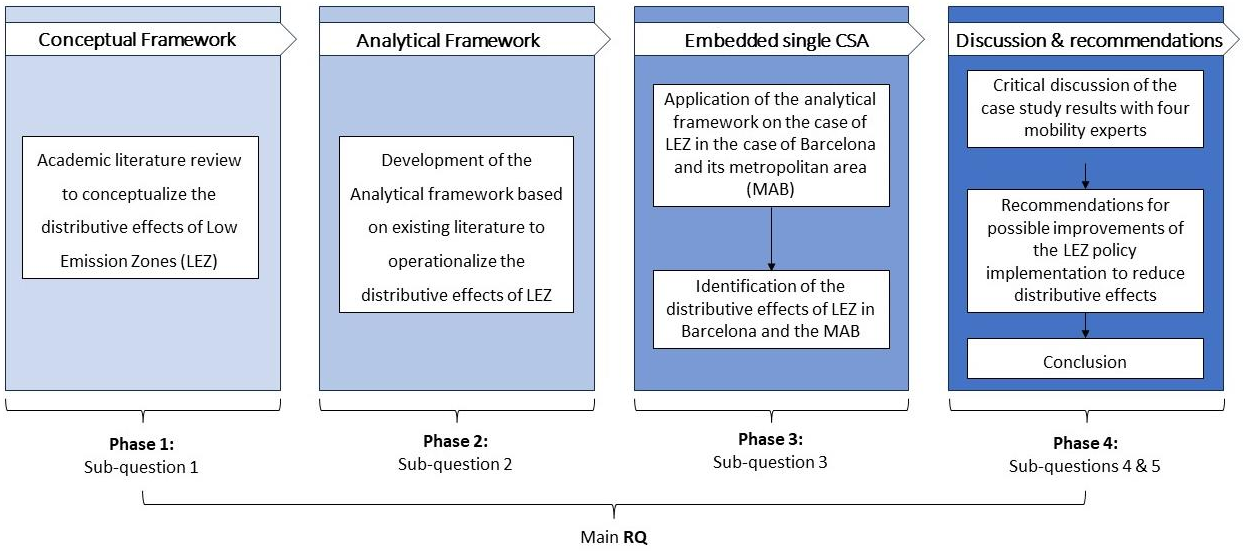

Figure 1. Research framework

1.5 Scientific and societal relevance of research

The distributional consequences of LEZ rules are a topic of great scientific and societal importance. There is a clear scientific gap in the field of climate governance, as the majority of the research on the subject focuses on how well LEZ policies succeed in reducing air pollution. Through examining the social and economic effects of the LEZ policy on a range of citizen groups within Barcelona (MAB), this study advances knowledge of how different societal segments are impacted by this policy and provides initial guidance on changes that may be required to achieve more equitable results (Moreno et al., 2022). The identification of distributional effects in Barcelona and the suggestions that are proposed for improving the policy provide significant contributions to the global discourse about developing sustainable urban climate policies (Verbeek & Hincks, 2022).

From a societal perspective, this research holds paramount importance for two distinct reasons: ethically, in that it aligns with societal principles and moral standards, advocating for what is considered right and just within a community; and functionally, as it offers practical benefits and

solutions, addressing real-world problems and contributing effectively to societal well-being and progress.

Addressing the distributional impacts of urban policies, such as Barcelona's LEZ, is crucial for reducing social injustice and increasing policy efficacy, which, in turn, secures public support (Mees et al., 2014). This necessity arises amid the dual challenges of combating air pollution and climate change while striving for social and economic fairness in expanding urban landscapes. The urgency for policies that meld sustainability with social justice is paramount as urban areas evolve under the pressures of climate change (Bulkeley & Betsill, 2013; McArdle, 2021). This study contributes to the development of more equitable urban climate policies by shedding light on the LEZ policy's distributional effects in Barcelona, illustrating the essential role of equity in crafting effective and inclusive urban sustainability strategies. Additionally, the context-specific exploration adds depth, recognising unique dynamics in sustainable policy introduction (Hughes & Hofman, 2020). Understanding these dynamics enables tailored policies addressing local needs and broader sustainability and justice goals. This research also raises awareness among policymakers about adopting intersectional frameworks addressing social and economic inequalities while promoting sustainability (McArdle, 2021; Amorim-Maia et al., 2022).

Ultimately, the recommendations derived from this research for mitigating the distributional effects of the LEZ policy in Barcelona have the potential to serve as a practical guide for policy improvement. This could result in a greater degree of acceptability of LEZs in Barcelona, enhancing the policy's effectiveness and aligning with broader literature emphasising the importance of effective policy implementation (Wang et al., 2018; Oltra et al., 2021; Riski et al., 2022).

2 Conceptual design and analytical framework

2.1 Relevant theories and approaches

The following literature review embarks on an exploration of the existing scholarship regarding the socioeconomic implications of LEZ implementation. It helps to understand the existing knowledge and theoretical views on the topic of LEZ policies and how they might affect various socio-economic groups. This section serves three purposes: first, it helps clarify the key concepts that underlie the distributional effects of LEZ policies, which will be further discussed in the following sections; second, it helps build the analytical framework that directs the empirical study. Thirdly, this literature analysis establishes the foundation for an in-depth discussion in which the study's results will be assessed critically in light of the existing body of knowledge.

Before diving into the academic literature on the specific topic of socio-economic implications of LEZs, it is important to mention that there is a general consensus within the academic community on LEZ policies being effective in reducing traffic-related air-pollution. There is extensive literature confirming this endeavour. A comprehensive study in Germany carried out by Morfeld et al. (2014) analysed the effectiveness of LEZs in 17 cities, focusing on the reduction of nitrogen oxides (NOx) and found that LEZs might reduce NOx concentrations effectively, although the scientific proof is still under development. Another study by Zhai & Wolf (2021) found that LEZs in London significantly reduced NOx and PM10 levels and improved air quality by restricting the most polluting vehicles. Bernardo et al. (2021) reported similar findings, with LEZs leading to measurable improvements in air quality in several European cities. Regarding the particular case of traffic-related air pollution reduction in Barcelona, there are no studies that have evaluated the tangible impacts of the LEZ policy on air pollution reduction. However, Rodriguez-Ray et al. (2022) study the effects of LEZ collectively with other traffic-related measures such as superblocks and tactical urban planning, confirming that the combination of said strategies does result in air-pollution reduction. These studies collectively indicate that LEZs can be an effective tool for reducing traffic-related air pollution, with observed improvements in air quality metrics in various urban settings.

The following segment of this review shifts its focus back to the **socio-economic implications of LEZ policies**. First, findings from diverse studies conducted in different cities with established LEZ initiatives are synthesised, shedding light on the overarching trends and commonalities that have emerged in these distinct contexts. By examining the experiences of these cities, this review aims to establish a comprehensive understanding of the broader implications of LEZ implementation, providing a foundation for a nuanced analysis of the specific case of the city under study.

Finally, the literature review turns its attention exclusively to the city of interest, Barcelona, offering an in-depth exploration of studies that investigate the socioeconomic impacts and distributional effects of the LEZ within the city. This location, as the focal point of this study, presents a unique case study with its own set of contextual nuances and challenges. By scrutinising the scholarly discourse surrounding Barcelona's LEZ, this review seeks to examine the existing body of knowledge and gain insights into the ways in which local dynamics, regulatory frameworks, and socioeconomic factors interact to shape the outcomes of LEZ initiatives.

Socio-economic implications of LEZ in European cities

To initiate this exploration, the attention turns to Verbeek & Hincks (2022). In this study, the authors aim to add a data-driven perspective to the discussion of whether LEZs have an unequal social impact on people's accessibility and finances by simultaneously analysing the unequal exposure to air pollution and its unequal impact in a comparative study of the LEZs in London and Brussels. The analysis combines a conventional multivariate regression analysis with geographically weighted regression (GWR) modelling to determine whether the implementation of LEZs in these cities leads to unfair effects on lower socioeconomic classes. In Brussels, it concludes that the environmental justice argument supporting the LEZ is strong, as the most polluted areas coincide with the LEZ, and there's an inverse relationship between air pollution exposure and household income. While the social justice argument against the LEZ is only partially valid due to better public transport in deprived areas, their research indicates that the current LEZ is insufficient, excluding the urban fringe and revealing unequal pollution exposure around the city centre. Contrastingly, London presents a weaker environmental justice case for the LEZ, with a scattered income-pollution pattern. The social justice argument against the LEZ is robust, particularly in lower-income areas with a higher proportion of non-compliant cars, poorer public transport, and limited air quality gains. This study is of special interest, as it is one of the few empirical studies on the topic and has served as a strong guide to developing the first part of the analytical framework, which is presented in Section 2.5.

Another relevant study is De Vrij & Vanoutrive (2022). The study examines the social implications of LEZ using the Antwerp LEZ in Belgium as a case study. The research challenges the perception that only households with non-compliant vehicles within the zone are impacted. It reveals broader social effects, including feelings of burden on residents and financial challenges for low-income car owners with older vehicles allowed in the zone. The study highlights the need to consider the perspectives of those most affected by such policy measures, and they do so by carrying out semi-structured interviews. Interviews reveal that car restrictions can lead to social exclusion, particularly impacting families with children and those dependent on cars for shopping. The study emphasises the limitations of the LEZ policy in addressing the needs of vulnerable groups, citing a democratic deficit.

The study by Moreno et al. (2022) assesses the Paris LEZ health and economic impacts, focusing on environmental justice. This assessment, although with an approach more focused on health, also contributes to the academic discourse of evaluating the socio-economic implications of LEZs. It utilises a health impact assessment to analyse the effects of air pollution reduction on socioeconomic groups across different LEZ scenarios. The findings indicate significant health benefits, but the distribution of these health benefits is not uniform across different socioeconomic groups. The research findings suggest that health benefits from LEZs tend to skew towards higher-income residents, who are often less exposed to traffic-related air pollution and might already possess vehicles that comply with LEZ standards. Furthermore, the study emphasises that while LEZs can lead to substantial economic benefits by reducing costs related to premature mortality and asthma, the policy implications and economic impacts on low-income individuals who may struggle with the stringent requirements of LEZs are significant. This research highlights the importance of considering equity in environmental policies to ensure benefits are distributed across all socio-economic groups.

Moreover, there are also many studies regarding sustainable transport, distributional effects, and social equity. An example would be a study titled “Distributional justice and equity in transportation” published in 2016 by Rafael H. M. Pereira, Tim Schwanen, & David Bannister. This paper examines the intersection of justice and transport policies, noting a lack of engagement with political philosophy theories. It reviews various justice theories and advocates for prioritising accessibility as a human capability, drawing on Rawlsian and Capability Approach perspectives.

The Rawlsian Approach, conceptualised by John Rawls in his seminal work "A Theory of Justice" (1971) and in his chapter "Political Liberalism" (1994), emphasizes justice as fairness, focusing on ensuring that social institutions distribute benefits and burdens in society equitably. Rawls' philosophy is built around the idea that if individuals were to choose principles of justice from an original position of equality, without knowledge of their own place in society, they would select principles that protect the weakest members and ensure fundamental liberties for all. This approach prioritises the creation of a just society through equitable principles that govern basic rights and the distribution of resources. The Capability Approach, developed by Amartya Sen and further elaborated by Martha Nussbaum, shifts the focus from resources or utility to what individuals are actually able to do and to be – their capabilities. This perspective argues that true well-being is not measured by the goods people have or their overall happiness but by their freedom to pursue a life they have reason to value. It emphasises the importance of providing individuals with the opportunities and freedoms to develop their capabilities, such as health, education, and participation in social activities, thereby offering a more nuanced understanding of poverty, inequality, and development. While the Rawlsian Approach focuses on principles of justice and fairness in opportunities, the Capability Approach puts more emphasis on the actual freedoms and abilities people have to achieve their valued ends. The suggested approaches involve analysing the distributional effects of transport policies, setting minimum accessibility standards, considering individual rights, prioritising disadvantaged groups, reducing opportunity inequalities, and mitigating transport externalities. The paper concludes that a more nuanced understanding of accessibility is crucial for a comprehensive account of justice in transportation.

David Bannister, a strong referent in the field of transport studies, has published many studies related to inequality in transport. The book “Inequality in transport” (2018), is of high relevance in the field, as it examines transportation inequality in Great Britain, the impact of this inequality on quality of life, and suggests ways that this inequality can be addressed. Moreover, he has also published more broad-base studies on justice in relation to sustainable transport, such as his book chapter “Moving towards sustainable urban transport: how can we integrate environmental, health and equity objectives globally?” in *Ensuring a Sustainable Future: Making Progress on Environment and Equity*, published in 2013. This chapter addresses the severe environmental challenges the world faces, such as air and water pollution, increased energy consumption, and the depletion of natural resources, emphasising their disproportionate impact on the poor. It critiques the gap in previous research that overlooks economically viable solutions benefiting both the environment and poverty alleviation. His research aligns well with the topic of this thesis, which also intends to gain more insight on the disproportionate impacts of LEZ policies on low-income populations and how this can be overcome.

Socio-economic implications of LEZ in the city of Barcelona

Considering Barcelona as the pivotal case study for this thesis, this section meticulously examines scholarly articles cantered on the socio-economic implications of the LEZ within the city. The critical review of these studies seeks to enhance understanding of the complex dynamics involved, thereby enriching the analysis of the case at hand. This comprehensive exploration sheds light on the existing knowledge of LEZ policies in Barcelona and helps to contextualise and deepen the understanding of this particular case.

The study published in September 2022 by Joan Checa Rius, David Andres Argomedo, and Núria Pérez Sans, "Analysis of the socio-economic impact in the territorial area of the Zona de Baixes Emissions Rondes de Barcelona", undertakes a comprehensive examination of the social and economic repercussions stemming from the implementation of the LEZ in Barcelona. The study encompasses various territorial areas, including the SIMMB area (Integrated System of Mobility Metropolitana de Barcelona), the province of Barcelona, the MAB, and the specific municipalities directly affected by the LEZ. There are three main sections to the study. First, examining daily movement patterns and economic inequality is the main goal of the first section. The study's specific objective is to identify differences in mobility behaviours among socioeconomically disadvantaged groups, which include women, the elderly, young people, and those with impairments. It also looks into the different access to private vehicles based on income levels and the Dirección General de Tráfico's (DGT) classification of environmental badges. The chapter also examines how accessible public transportation is in relation to various socioeconomic brackets. In the study's second section, the focus is on the socio-economic and geographical effects of Barcelona's implementation of the LEZ. It is noteworthy that this chapter gives special attention to low-income individuals who commute within the boundaries of the LEZ. The study's third and final section assesses the compensatory measures and progressive adaptation techniques used in response to the LEZ's automobile traffic restrictions. The principal aim is to acquire knowledge regarding the actions coordinated by capable governments to mitigate the effects of these limitations.

The investigation's main conclusions highlight the tendency of those with lower incomes to use private vehicles less frequently. Nonetheless, lower-income neighbourhoods have a greater prevalence of cars registered without the required environmental emblem. Remarkably, daily mobility data in the ZBE show that the effects of traffic limitations are not disproportionately felt by lower-income groups. Moreover, the study concludes that competent administrations have taken income into account while issuing authorizations for everyday circulation. The study also emphasises the wider benefits to society of implementing a more health-conscious and sustainable mobility strategy, especially for those who are less dependent on private vehicles.

Oltra et al. (2020) published another relevant study of LEZ in the context of Barcelona. The article starts by outlining the main factors that play a role in public acceptance of LEZ policies. Through an in-depth literature review of studies done in other regions, the authors conclude that there are eight primary factors that influence public acceptance: sociodemographic variables; car ownership and dependence; problem perception; prior values, orientations, norms, and attitudes; perceptions and beliefs about policy characteristics; institutional trust; perceived process legitimacy; and emotional dimensions. For this study, residents of Barcelona were asked to self-administer an online survey as part of the study.

The study reports high public acceptance of the implementation of the LEZ in Barcelona, with residents perceiving it as effective in reducing air pollution and fair. The study's findings demonstrated that the acceptance of the LEZ was significantly correlated with beliefs, affect, perceived legitimacy, and trust related to the policy, and to a lesser extent, with people's preexisting attitudes toward car ownership, problem perception, pro-environmental self-identity, and pedestrianisation, as well as sociodemographic factors, primarily car ownership and political ideology. However, the study acknowledges limitations, such as a non-representative sample. The authors acknowledge that their population sample includes more educated and young respondents compared to the general population. Taking into consideration the fact that personal and political beliefs, as well as perceived legitimacy, are the main factors playing a role in public acceptance, having more highly educated and young respondents could have easily biassed the results towards a higher degree of acceptance. Morton et al. (2021) titled "Public acceptability towards LEZ: The role of attitudes, norms, emotions, and trust", also confirm the fundamental role that attitudes, views about particular policies, confidence in the government, and problem awareness all play in terms of their direct and indirect influences on acceptance.

Moreover, another study by Amorim-Maia et al. (2023), slightly contradicts the findings of the previous study. This article looks at eight climate interventions that have been implemented in Barcelona between the years of 2015 and 2023, all of them under the governance of the same mayor, Ada Colau. For each intervention, they look at the outcomes and beneficiaries as well as the lessons learned from them. One of the climate interventions the authors investigate is indeed the LEZ policy, and the study concludes that the initiative has a general citizen rejection, especially amongst low-income car-dependent workers.

The contrast between the studies by Oltra et al. (2020 and Amorim-Maia et al. (2023 reveals the importance of taking into consideration people from all classes and backgrounds in order to have a better understanding of people's experiences and perceptions.

Conclusion of theories and approaches

This literature review provides a comprehensive examination of the literature related to the socioeconomic implications of LEZ, focusing on their effectiveness in reducing traffic-related air pollution and the broader societal implications, particularly in terms of distributional effects and social justice concerns. It synthesises findings from various studies conducted in different cities with established LEZ initiatives, offering a foundation for understanding the environmental benefits of LEZs while emphasising the need for further research into their social impacts, especially in Barcelona.

The selection of literature is representative and balanced, encompassing studies that assess the environmental effectiveness of LEZs, their health and economic impacts, and their perceived fairness among the public. It includes empirical studies that offer data-driven insights into the LEZs' impacts on social equity and accessibility, theoretical discussions on the principles of justice in relation to transport policies, and specific case studies from cities like London, Brussels, Antwerp, Paris, and Barcelona. This selection contributes significantly to the thesis by highlighting the critical gap in understanding the social justice implications of urban environmental policies, particularly LEZs, and setting the stage for the empirical analysis of Barcelona's LEZ policy. Moreover, this review serves as an input to the conceptual and analytical

framework, as it establishes the context within which LEZ policies operate, their potential benefits, and the concerns regarding their distributional effects. It underlines the importance of considering both environmental and social outcomes to ensure that LEZ policies contribute to a more sustainable and equitable urban future. By doing so, it lays a solid foundation for the thesis's investigation into the distributional effects of Barcelona's LEZ policy.

2.2 Social Justice

After having delved into the existing literature on the topic of LEZ and their socio-economic implications, it is clear that the concept of social justice is essential to the broader debate in which this thesis is positioned. Therefore, it is highly important to understand this concept, particularly in the context of climate change and climate policies.

Climate change is a multifaceted challenge that intersects with issues of justice, underscoring the need for a comprehensive examination of environmental justice within the context of climate change governance (Malloy & Ashcraft, 2020). Failing to address issues of justice in climate change governance can perpetuate existing societal inequalities by favouring those already in privileged positions and reinforcing the vulnerabilities of marginalised communities (Adger, 2006; Malloy & Ashcraft, 2020).

There exists no singular, all-encompassing definition of justice (Pereira, et al., 2016). Nonetheless, within academic literature focused on environmental justice, two key dimensions are frequently discussed. **Procedural justice**, which centres on the fairness of the decision-making process, encompasses aspects such as participatory mechanisms and equal access to information (Adger et al., 2006). In contrast, **distributional justice** focuses on the fair allocation of benefits and burdens associated with environmental activities, as well as the mitigation of related risks. This perspective on distributional justice aligns with the 'Egalitarian' principle, which holds that resources should be distributed equally amongst all individuals (Meyer & Roser, 2006), or when looking at outcomes, it can be interpreted as that all actions taken should aim for an equal distribution of outcomes (Jafino et al., 2022; Konow, 2003).

While procedural justice is undeniably crucial in environmental justice discourse, this thesis strategically centres its attention on distributional justice, particularly in the context of LEZ policies. The rationale for this emphasis lies in the aim of assessing tangible outcomes and impacts on the population affected by environmental policies. Distributional justice, with its focus on the equitable allocation of benefits, burdens, and risk mitigation, allows for a nuanced exploration of how environmental policies manifest in real-world scenarios. By emphasising distributional justice, the thesis seeks to unravel the actual consequences of LEZ policies on different socio-economic groups and communities within Barcelona and its metropolitan area. Understanding the distributional implications provides essential insights into the tangible effects of these policies on individuals and communities, offering a pragmatic perspective that aligns with the overarching goals of this research.

A crucial aspect of assessing distributional justice in environmental policy is that every household is unique, and climate policies will exert distinct effects on each of them. Nevertheless, households sharing similar characteristics are likely to experience relatively comparable impacts. Several factors influence how households respond to a particular climate policy, including attributes such as gender, nationality, wealth, income, ethnicity, geographic

location, occupation, and educational attainment (Zachmann et al., 2018). Income, in particular, often takes centre stage in research and political discussions as a pivotal factor (Zachmann et al., 2018). Consequently, this study's primary focus centres on assessing the distributional effects of climate policies on households across various income levels.

Extensive literature on distributional justice and climate policy effects categorises policies based on their impact on the population, classifying them as regressive, progressive, or proportionate. If a policy disproportionately burdens low-income households, it is considered regressive; if high-income households bear the disproportionate burden, it's progressive; and if costs are uniformly distributed, it's proportionate (Büchs et al., 2011; Zachmann et al., 2018; Ohlendorf et al., 2020). The literature generally indicates a tendency for regressive impacts, especially in developed countries, with a consensus that a major drawback of climate policies is their disproportionate impact on lower-income groups.

2.3 Conceptual framework

Following the literature review of relevant theories and approaches, this section aims to answer sub-question 1, *"Which potential distributional effects can be derived from previous research regarding LEZ policies, other climate-related transport policies and relevant literature?".* In public discourse and policy discussions, LEZs have been advocated as a means to implement the "polluter pays" principle, aiming to offer advantages to marginalised communities that face higher exposure to air pollution despite contributing less to it. However, after the previous detailed literature exploration of the socioeconomic implications of LEZs, it is clear how, when looked at from a critical perspective, it can be seen how LEZs do not always offer advantages to marginalised communities, potentially creating disparities in spatial access and imposing disproportionate financial hardships on socio-economic groups already at a disadvantage.

Within this dimension, and also based on different academic studies done on the same or similar topics, two major possible distributional effects of LEZ have been identified:

A. Mobility and accessibility restrictions

The first factor that is looked into in order to find out the potential distributional effects of LEZ policies lies in the examination of inequalities in mobility and accessibility levels. On one hand, mobility is defined in academic literature as the capacity to move and travel between different locations. Mobility restrictions come into play when specific transportation modes, routes, or travel choices are limited or subject to regulation (Pereira et al., 2016)

Conversely, accessibility refers to the ease with which individuals can reach destinations and opportunities from their locations (Handy, 2020). In academic literature, there's a strong consensus that accessibility is central to the social justice and social inclusion agenda, recognized as pivotal for ensuring individuals' freedom and equal opportunities (Church et al., 2000; Farrington & Farrington, 2005; Delmelle & Casas, 2012; Welch, 2013). Equal access to essential public services, like health and education, along with access to a diverse job market and other valuable social resources, is fundamental for fostering justice within society (Setianto & Gamal, 2020). Achieving equal accessibility faces challenges due to the uneven distribution of public services, often concentrated in major urban centres, and a broader range of job opportunities. This spatial disparity puts individuals in suburban areas at a distinct disadvantage in accessing crucial amenities (Charleaux, 2013; Setianto & Gamal, 2020).

The introduction of LEZ in urban centres exacerbates challenges for socio-economic groups, potentially deepening existing disparities. LEZ restrictions can disproportionately burden individuals from disadvantaged groups, posing challenges in adapting to changes in transportation options and navigating transformed urban landscapes (Charleaux, 2013; De Vrij & Vanoutrive, 2021). Notably, those with lower incomes often own older vehicles that don't meet LEZ emission standards, limiting mobility and access to these zones. Additionally, outer-city and suburban areas, where a higher proportion of lower-income residents live, typically have less extensive public transportation networks (De Vrij & Vanoutrive, 2022). Consequently, there is a significant likelihood that LEZ policies may disproportionately affect the mobility and accessibility of lower-income populations (Charleaux, 2013).

B. Economic Burden

The second factor that is looked at to assess the potential distributional effects of LEZ policies is the economic burden faced by the population and how it differs between high- and low-income households. It is speculated that low-income factors might face a greater economic burden from LEZ policies. As already mentioned, they are more likely to own older cars that are restricted from circulating within a LEZ. This could lead to a greater struggle to afford the necessary vehicle upgrades, or you may be unable to do so without financial assistance. This could then lead to a reinforcement of the previously described impacts of decreased mobility and accessibility, tying all two potential distributional effects together (Charleaux, 2013).

2.4 Analytical framework

In this section, sub-question 2 is answered, and the analytical framework for evaluating the distributional effects of LEZ policies is developed according to the insights gained from the literature review and the conceptual framework. The proposed study's analytical framework is designed to be comprehensive, encompassing both quantitative and qualitative research techniques, and structured in two distinct phases.

Initially, a thorough statistical correlation analysis was conducted to examine the numerical relationships and trends within the data. This was followed by a qualitative survey aimed at gathering in-depth insights and perspectives that go beyond the scope of quantitative analysis. This dual approach ensures a balanced and thorough exploration of the study's subject matter. In Table 1, a summary of the analytical framework is provided.

Table 1. Analytical framework

FIRST PART: STATISTICAL CORRELATION ANALYSIS – QUANTITATIVE INDICATORS			
Indicators	**Description**	**Operationalizes**	**Sources**
1. Median Household Income	○ Evaluates economic impact ○ Indicates financial disparities ○ Operationalizes socioeconomic status	B. Economic burden	Galobardes et al., 2006; De Vrivj & Vanoutrive, 2022; Verbeek & Hincks, 2022
2. Proportion of Non-Compliant Cars	○ Assesses mobility impact ○ Reveals LEZ access challenges ○ Indicates impact on essential services	A. Mobility and accessibility restrictions	Verbeek & Hincks, 2022; Pereira et al., 2016
3. Quality of Public Transport	○ Assesses modal shift feasibility ○ Examines accessibility and economic impacts ○ Compares travel time of public and private transport	A. Mobility and accessibility restrictions B. Economic burden	Verbeek & Hincks, 2022; Shico et al., 2019
4. Percentage reduction of non-compliant cars	○ Gauges economic impact ○ Reflects willingness to invest in compliant vehicles ○ -Highlights economic adaptations and disparities	B. Economic burden	Verbeek & Hincks, 2022
SECOND PART: QUALITATIVE SURVEYS ON THE EXPERIENCES AND ADAPTATION TO THE LEZ OF THE POPULATION AT THE NEIGHBOURHOODS OF PEDRALBES AND CIUTAT MERIDIANA			
Purpose	Comprehensive evaluation of potential disparities resulting from the LEZ policy in Barcelona across various socioeconomic groups.		
Themes of the survey	- Awareness and understanding of LEZ - Social and community effects - Economic impact - Adaptation strategies - Overall Satisfaction		

Significance	Qualitative surveys provide data which provides context and depth to the statistical findings. Helps understand the complex phenomena of LEZ distributional effects.	Seixas et al., 2017 Braun et al., 2020

Drawing inspiration from the work of Verbeek & Hincks (2022), the first part of the analytical framework for this study was shaped, focusing on four quantitative indicators: household income, proportion of non-compliant cars, quality of public transport, and percentage reduction of non-compliant cars. Verbeek & Hincks (2022) developed for their study a set of indicators, which include the first three indicators used for this thesis, that allowed them to assess the accessibility and economic burden impact of LEZs in Brussels and London. Given the similarities in the objective of their study to that of this thesis, the logic of their justification, and the interesting results of the study, it was decided that it would be interesting to adopt a similar approach for this thesis. These indicators are useful for assessing the potential impacts of the LEZ on mobility, accessibility, and the economic conditions of various socio-economic groups. These indicators will be meticulously calculated to provide a comprehensive understanding of the LEZ's effects.

1. **Median Household Income:**

The median household income serves as a crucial metric to evaluate the economic repercussions of LEZs. Higher median incomes typically indicate greater financial resources available within a community. By examining income levels, it can be discerned whether LEZ policies are disproportionately affecting lower-income households. A thorough analysis of median income helps illuminate economic disparities that may emerge due to mobility restrictions or the associated costs of complying with LEZ regulations.

The choice of household income as the key indicator to operationalize socioeconomic status is justified by its comprehensive reflection of economic well-being and social standing within a community. Household income encapsulates the financial resources available to a family unit, offering a holistic perspective on its capacity to cope with the consequences of climate policies (Galobardes et al., 2006; De Vrivj & Vanoutrive, 2022; Verbeek & Hincks, 2022). Moreover, income is a versatile metric that integrates various aspects of socioeconomic status, encompassing employment status, job security, and overall financial stability (Galobardes et al., 2006). This allows for a nuanced analysis of how climate policies may disproportionately affect different income groups, shedding light on potential disparities in their ability to adapt and thrive in the face of environmental changes.

2. **Proportion of Non-Compliant Cars:**

The proportion of non-compliant cars per municipality offers valuable insights into the mobility & accessibility impacts of LEZ. Non-compliant vehicles are typically barred from entering LEZs due to not meeting emission standards (Verbeek & Hincks, 2022). This indicator assists in approximately assessing the proportion of residents that may encounter challenges when attempting to access LEZ areas. Such challenges can significantly impact their ability to reach essential services and opportunities, including employment, healthcare, or educational facilities, within these restricted zones (Pereira et al., 2016).

3. **Quality of Public Transport:**

Assessing public transport quality is crucial to understanding the ease of a modal shift from private to public transport, considering both accessibility and economic impacts (Verbeek & Hincks, 2022). A robust public transport system mitigates the accessibility impact of LEZs, providing alternatives for affected residents and reducing the financial burden on households that might otherwise need to replace non-compliant vehicles. Scrutinising public transport quality helps measure the effectiveness of transit options and their role in shaping accessibility and the economic landscape.

4. **Percentage reduction of non-compliant cars:**

This indicator evaluates the economic impact of LEZ by analysing the percentage reduction of non-compliant cars, shedding light on the extent of economic efforts households undertake to align with LEZ policies. It offers insights into the capacity and willingness of residents to make financial adjustments, such as purchasing compliant vehicles, in reaction to LEZ regulations (Verbeek & Hincks, 2022). A lower percentage of non-compliant cars might reflect proactive economic adaptations, whereas a higher percentage could indicate constraints—financial or otherwise—limiting the population's ability to acquire or opt for compliant vehicles or simply less need to do so. Importantly, examining these economic adjustments becomes particularly crucial in understanding how lower-income households navigate the financial pressures imposed by LEZ policies. This focus underscores the potential for economic disparities to deepen, as these households may face significant challenges in making the necessary adjustments.

By considering these four indicators, a holistic analytical framework is constructed that comprehensively examines both the accessibility and economic impacts of LEZs in Barcelona and the MAB. This approach yielded valuable insights into how the LEZ policy influences different socio-economic groups, thereby informing future urban planning and transportation strategies.

The second part of the analytical framework consists of acquiring qualitative data and insights from the population of the richest and poorest neighbourhoods in Barcelona, Pedralbes and Ciutat Meridiana, to effectively assess the distributional effects arising from the LEZ policy in different socioeconomic groups. Understanding the impact of LEZ policies requires more than just numbers. While quantitative metrics effectively show the immediate effects of these policies, a deeper, qualitative approach is also essential to better understanding the population's experiences. The combination of both quantitative and qualitative data helps get a full picture of how LEZ policies truly affect different communities (Seixas et al., 2017). Such research offers a detailed analysis of personal experiences and the socioeconomic context in these areas. Involving those directly affected by the LEZ policy can yield critical firsthand information, significantly enhancing the credibility and depth of research findings (Seixas et al., 2017).

Concentrating on economically disadvantaged areas sheds light on the specific challenges faced by lower-income households. It uncovers potential unfairness brought about by the LEZ policy, such as limited access to alternative transportation or a heightened financial burden. Similarly, surveying residents in wealthier neighbourhoods aims to uncover possible advantages and factors that mitigate the impact of the LEZ policy on their lives (Charleaux, 2013; De Vrij & Vanoutrive, 2022).

This approach facilitated the examination of whether the policy's influence on daily life, economic concerns, and transportation choices markedly differs between these two socio-economic extremes. This revealed whether the policy aggravates existing socioeconomic inequalities or contributes to a more equitable shift to a sustainable transport model. Moreover, qualitative description, which focuses on accurately presenting participants' stories and meanings, is an effective way to explore viewpoints without introducing biassed interpretations (Seixas et al., 2017).

3 Methodology

3.1 Research strategy – Embedded single case study

This section presents the description and justification of the chosen research strategy for this thesis, an embedded single case study analysis (CSA).

A case study is a versatile research method widely used, especially in the social sciences, to attain a comprehensive understanding of complex issues in their real-life contexts. Its primary aim is to thoroughly examine events or phenomena within their natural context, offering the potential to describe, explain, or explore occurrences in daily contexts. Case studies are instrumental in comprehending causal connections and paths, making them an appropriate strategy for the proposed research (Gerring, 2004).

As already mentioned, for the proposed research, an embedded single CSA of the LEZ policy in Barcelona was carried out. An embedded single CSA is a research design that involves the in-depth examination of a single case while simultaneously considering the wider context in which it is embedded. This approach allows for a deep understanding of the case while also enabling the researcher to examine the broader contextual factors that may influence the case, making it a suitable design to carry out the planned research (Budiyanto, et al., 2019).

In the case of the proposed research on the distributional effects of the LEZ policy in Barcelona, the context of the embedded case study is the city of Barcelona, where the LEZ policy has been implemented, and its metropolitan area, where the LEZ is highly likely to be felt. The case is the LEZ policy itself and its potential distributional effects on the population living and working in Barcelona and its metropolitan area. The embedded units of analysis are the different subgroups of the population being analysed to see how LEZ has affected them. These subgroups are low, medium, and high-income households. Although the research focuses on the LEZ policy implemented in Barcelona, the assessment of the distributional effects will not be restricted to the population that falls within the borders of the LEZ. This thesis analyses both the 73 neighbourhoods of Barcelona and the 36 municipalities that comprise the MAB. The benefit of adopting study areas that are more spatially extensive than the LEZs themselves is that it allows us to analyse “edge effects”, where mobility and accessibility impacts as well as economic impacts are likely to transcend the boundaries of the LEZs (Su et al., 2010; Verbeek & Hincks, 2022). Finally, as the second part of the analytical framework involves gathering qualitative data on the LEZ impacts in one high- and one low-income neighbourhood, sub-units have been included within the embedded units of high- and low-income households (Figure 2). The two neighbourhoods chosen for the study are Pedralbes and Ciutat Meridiana, based on their contrasting socioeconomic statuses but similarities in the quality of public transport available, which is poor. Pedralbes is noted for its economic affluence, while Ciutat Meridiana is identified for its economic challenges and poor public transport quality. These distinctions offer a broad comparative perspective to analyse the impacts of the LEZ policy, highlighting the distributional effects and adaptation strategies to urban policies within diverse urban settings.

Therefore, an embedded single CSA is considered an appropriate research strategy for the proposed thesis. This approach allows for a detailed and in-depth examination of the policy's impacts on the population, both within the city of Barcelona and the surrounding municipalities

in the MAB, providing insights into the impacts of the policy on different population groups, particularly those who are socially disadvantaged.

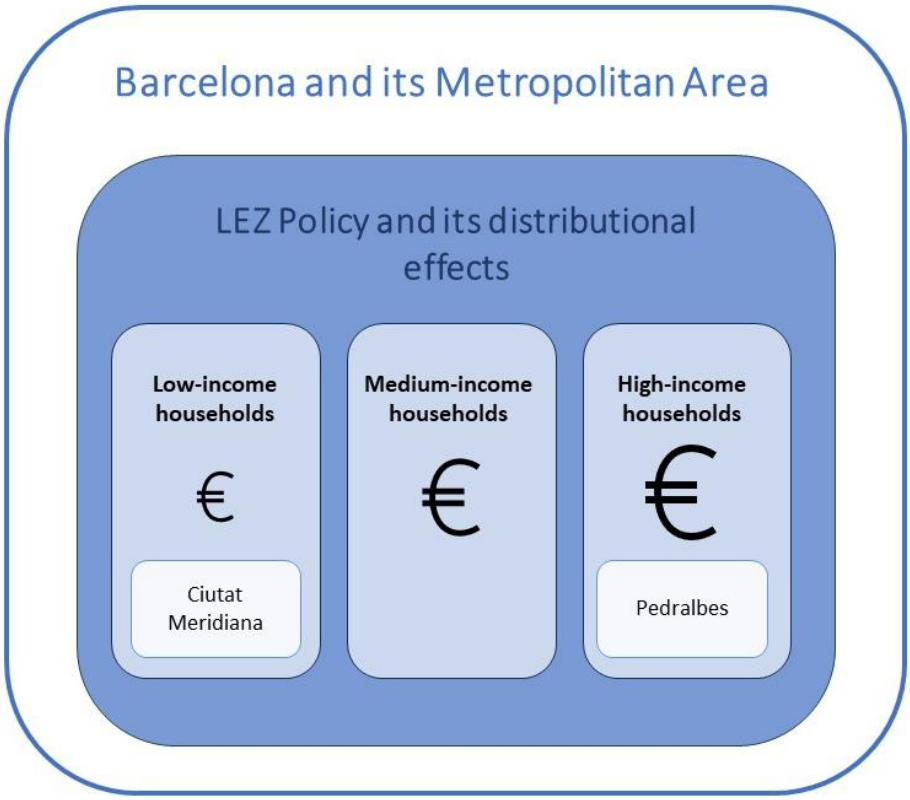

Figure 2. Embedded single CSA design (Source: Own elaboration)

3.2 Case description

Building on the outlined research strategy, the following section delves into the case study of Barcelona, chosen for its distinct environmental challenges and pioneering LEZ policy. This contextual groundwork lays the foundation for examining the policy's nuanced impacts across diverse urban settings. Following, a detailed description of the chosen case study of Barcelona is presented, along with the rationale behind its selection.

Barcelona is one of the most polluted cities in Europe (Cyrys et al. 2012; Eeftens et al. 2012). Barcelona's air quality issues are highly influenced by its topographical characteristics (Schembari et al., 2014). The city is located in a natural bowl-like depression, surrounded by the Collserola mountain range and other hills, which restrict the dispersion of pollutants. This setting, combined with its coastal location near the Mediterranean Sea, results in a unique microclimate where pollutants can become trapped in the city. The sea breezes also contribute to this trapping effect under certain atmospheric conditions, such as thermal inversions, where a layer of warm air sits above cooler air near the ground, further preventing the dispersion of pollutants (Schembari et al., 2014). This combination of physical geography and climatic conditions creates a challenging environment for maintaining clean air in Barcelona. These factors, coupled with the extreme high density of vehicles, significant traffic congestion, and limited green spaces, hinder the effective dispersion of pollutants, leading to higher concentrations of nitrogen dioxide and particulate matter. Furthermore, industrial activities in and around the city contribute to the pollution levels (Schembari et al., 2014; Reche et al., 2011).

In response to these pressing environmental challenges, Barcelona has implemented the LEZ policy, a critical measure designed to mitigate pollution levels and foster a healthier urban environment (Rius et al., 2022). Detailed next, this policy's framework and anticipated impacts underscore the city's proactive approach to environmental sustainability.

The Barcelona LEZ came into effect in January 2020 and it consists of a protected area of over ninety-five square kilometres, which encompasses Barcelona and the municipalities adjacent to the ring roads, where vehicles without a specific environmental label cannot travel (figure 3) (Medi ambient i sostenibilitat, n.d.). The restricted vehicles include petrol cars registered before the Euro 3 standard (before 2000); diesel cars registered before the Euro 4 standard (before 2005 or 2006); motorcycles registered prior to Euro 2 (before 2003) (Medi ambient i sostenibilitat, n.d.).

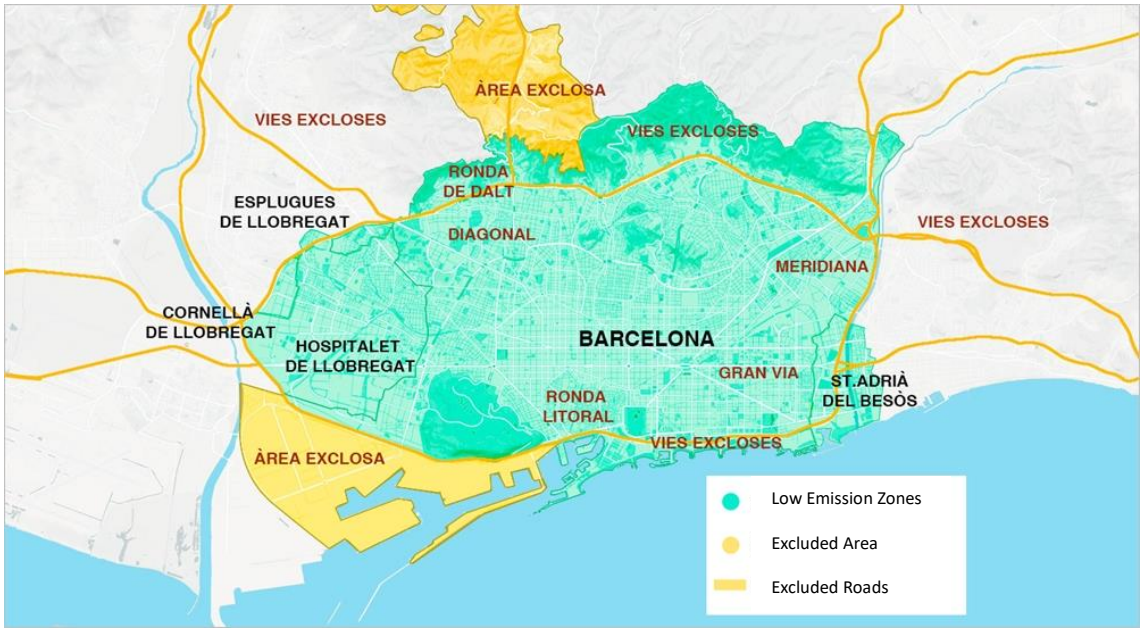

Figure 3. Map of the LEZ in Barcelona (Source: Medi ambient i sostenibilitat, n.d.)

The LEZ policy is anticipated to yield significant environmental and public health benefits. The primary intended outcome is the reduction of air pollution levels, which is linked to improved respiratory health among the urban population. Furthermore, the policy is expected to encourage the use of cleaner transportation options, thereby contributing to the long-term sustainability of the city (Medi Ambient I Sostenibilitat, n.d.). It is imperative to analyse how these outcomes manifest across various income groups, as the benefits and burdens of environmental policies are often unevenly distributed. This research, therefore, seeks to ascertain whether the policy achieves its environmental goals without disproportionately affecting lower-income households.

The implementation of the LEZ policy in Barcelona not only marks a significant step towards pollution reduction but also sets the stage for this research to evaluate its effectiveness and equity across different socioeconomic groups. The inclusion of both the city of Barcelona and its surrounding metropolitan area as units of analysis not only provides a comprehensive view of the LEZ's impact but also introduces a novel approach by investigating the 'edge effects'—a concept underscoring the indirect consequences of these policies beyond their immediate

geographic boundaries. This dual focus on direct and peripheral impacts signifies a pivotal step towards developing more inclusive and equitable environmental policies.

Therefore, the assessment of the distributional effects will be analysed within the 73 neighbourhoods of Barcelona (Figure 4) and the 36 municipalities that comprise the MAB (Figure 5).

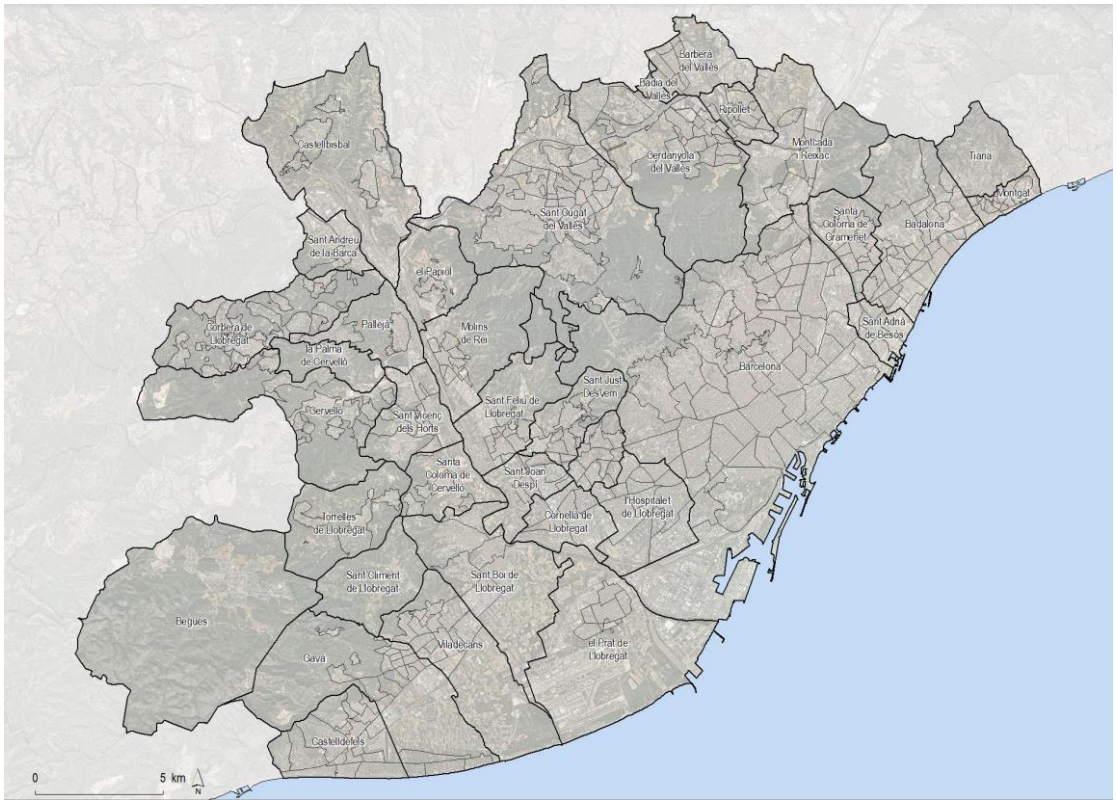

Figure 4. Map of the Neighbourhoods of Barcelona (Source: Institut Metropolis, 2016)

Figure 5. Map of the Metropolitan Area of Barcelona (Source: Area Metropolitana de Barcelona, n.d.)

Barcelona's 73 neighbourhoods collectively house 1.6 million inhabitants, accounting for half of the 3.2 million inhabitants residing within the MAB's 36 municipalities (Oficina Municipal de Dades, 2023). The entire area of the MAB spans 636 km2 (Metropolitan Area of Barcelona, n.d.). As mentioned earlier, including the MAB municipalities as units of analysis allows us to learn more about the “edge effects” of the LEZ. This approach is important because a high percentage of the population from these municipalities commutes to Barcelona for work, study, or leisure and, therefore, is indirectly affected by the LEZ policies. Additionally, assessing the experiences of the population of the MAB municipalities alongside the experiences of the population of the neighbourhoods in Barcelona provides a broader perspective on the distributional effects of the LEZ policies in the Barcelona region.

The rationale and justification behind the decision to carry out an embedded single CSA in the case of LEZ in Barcelona are not merely for the potential representativeness of the case but due to its unique environmental and socio-economic context. The case of Barcelona can be considered representative for its analysis of distributional effects on different income groups. The focus on assessing the distributional effects of the LEZ policy on low, medium, and high-income households is representative of a broader concern in urban policy research. It reflects an established practice of examining how urban policies impact different socio-economic groups within a city or metropolitan area. Moreover, the attention to "edge effects" where the impacts of mobility, accessibility, and economics transcend the boundaries of the LEZs, aligns with a common consideration in urban studies. This acknowledges that urban policies often have effects that go beyond their immediate geographical limits (Su et al., 2010; Verbeek & Hincks, 2022). Finally, this particular embedded single CSA can serve as a critical case for theoretical contribution as it will contribute to the broader discourse on sustainable urban development,

environmental justice, and the efficacy of LEZ policies, making it critical for theoretical advancements. Therefore, the findings of this study can then be used to better understand the phenomenon in a larger context (Gerring, 2004).

Contrastingly, the uniqueness of the case stems from the specific context of Barcelona and can therefore be considered a “unique” or “extreme” case. Barcelona's high pollution levels and the recent implementation of the LEZ policy in 2020 (Medi Ambient i Sostenibilitat, n.d.) present a unique scenario for studying the environmental and social impacts of such interventions. Moreover, it can also be seen as a revelatory case, given the scarcity of empirical studies on the social justice aspects of LEZs. Barcelona's case provides a revelatory opportunity to explore unexamined areas of LEZ policy impacts (Budiyanto et al., 2019). Therefore, studying Barcelona's case contributes to understanding how LEZ impacts diverse social groups, informing the development of more equitable and effective environmental policies.

The case study starts descriptive, offering a detailed account of the Barcelona LEZ (Omair, 2015). However, the study goes beyond mere description, adopting a revelatory approach (Ridder, 2017). The revelatory nature is emphasised by considering 'edge effects,' examining how mobility, accessibility, and economic impacts extend beyond LEZ boundaries. By examining both the city and its metropolitan area, the research aims to deepen the understanding of how LEZ policies can affect different social groups, contributing to the development of more equitable and effective environmental policies in urban settings.

3.3 Research materials

In Section 2.4 an analytical framework has been developed to analyse the distributional effects of LEZ. In this section, the details of the collection of the necessary data for each empirical step of the methodological approach are provided.

First, existing academic literature obtained through desk research was used to answer sub-questions 1 and 2 and to contextualise the embedded single CSA. The adoption of desk research is driven by its effectiveness in systematically reviewing and analysing existing literature, documents, and relevant materials related to the research topic. Quantitative data on the four indicators presented in the analytical framework was gathered, and a qualitative survey was utilised. Additionally, four interviews were carried out with mobility experts with the goal of validating the research results and gaining more qualitative insights on the topic. In the following sections, a detailed explanation of the data collection and data analysis process for each empirical step is provided.

3.4 Quantitative analysis: – Statistic correlation analysis

3.4.1 Data Collection

In Table 2, a summarised display of the data collection for the four indicators used in the first part of the methodological approach is provided. Following this, a more detailed explanation of how this data was collected and calculated is provided.

Table 2. Quantitative data collection

Indicator	Type of data	Sources	Accessibility
Household income	Gross household disposable income (GHDI) per municipality in the MAB 2020	IDESCAT, 2020 (most recent)	Publicly available
	Household disposable income (HDI) per neighbourhood in BCN 2019 and 2020	BCNROC, 2019	Publicly available
Non-compliant vehicles (% out of total cars)	Fleet of vehicles per municipality in the MAB	IDESCAT, 2022	Publicly available
	Vehicle environmental level census per municipality in the MAB	DGT en cifras, 2022 (only census avaliable)	Publicly available
	Fleet of vehicles per neighbourhood in BCN	Ajuntament de Barcelona, 2019 & Ajuntament de Barcelona 2021	Publicly available
	Vehicle environmental level census per neighbourhood in BCN		
Public transport quality	Average additional travel time by public transport (min)	Google Direction API	Publicly available
Percentage reduction of non-compliant cars	Percentage difference of non-compliant cars per neighbourhood in BCN	Ajuntament de Barcelona, 2019 & Ajuntament de Barcelona 2021	Publicly available

1. Household income

For every municipality in the MAB, household income data were acquired from the statistical institute of Catalunya (IDESCAT), which annually furnishes information on the gross disposable household income (GDHI) per inhabitant in each municipality. The data include both the total in euros per year and an index, with the average GHDI in the MAB set at 100. The most recent available data, from the year 2020, was utilised.

In the case of household income data for each neighbourhood in Barcelona, the Barcelona City Council's Open Knowledge Repository (BCNROC) was the source. BCNROC provides information on the household disposable income (HDI) per inhabitant in each neighbourhood of Barcelona, presenting both the total in euros per year and an index, with the average HDI in Barcelona set at 1.00. The data from 2019 was employed.

In the analysis of GDHI across municipalities in the MAB, a classification system was employed to categorise these municipalities into high, medium, and low-income groups based on their GDHI index relative to the set Catalonian average of 100. For the year 2019, the calculated average GDHI index for the municipalities in the MBA is 105.1. A 20% threshold around the average GDHI index was applied to provide a clear yet flexible demarcation between different income groups, facilitating a comprehensive understanding of the economic landscape in the region.

For this study, municipalities will be classified as follows:

- **High-Income Municipalities**: These will include municipalities where the GDHI index is at least 20% above the determined average of 105.1. Therefore, any municipality with a GDHI index of 126.12 (105.1* 1.20) or higher will fall into this category.
- **Medium-Income Municipalities**: This category will encompass municipalities with a GDHI index that is within 20% above or below the average of 105.1. Thus, municipalities with a GDHI index between approximately 84.08 (105.1* 0.80) and 126.12 will be considered to have medium income.
- **Low-Income Municipalities**: Municipalities in this group will be those with a GDHI index more than 20% below the average of 105.1. Consequently, any municipality with a GDHI index lower than 84.01 will be classified as low-income.

When categorising neighbourhoods in Barcelona into income groups based on the DHI index, the average DHI for the city is set at 100. This figure serves as the benchmark for comparison. In alignment with the methodology employed by the BCNROC in 2022 a threshold of 30% will be applied to define the income categories. This wider threshold is adopted to reflect the classification system used in existing studies by the BCNROC, ensuring consistency with established research.

The neighbourhoods are classified as follows:

- **High-Income Neighbourhoods**: Neighbourhoods with a GDHI index exceeding the city average by more than 30% are classified as high-income. This corresponds to a GDHI index of 130 or above.
- **Medium-Income Neighbourhoods**: Neighbourhoods with a GDHI index within 30% of the city average, either above or below, are classified as having medium income. Thus, neighbourhoods with a GDHI index between 70 and 130 are categorised within this group.
- **Low-Income Neighbourhoods**: Neighbourhoods with a GDHI index falling more than 30% below the city average are classified as low-income, which equates to a GDHI index below 70.

The choice of a 20% threshold for classifying municipalities within the MAB into income categories, as opposed to the 30% threshold used for Barcelona's neighbourhoods, is rooted in the differing levels of income inequality. The municipalities exhibit a lower rate of inequality compared to the diverse socio-economic landscapes of Barcelona's neighbourhoods. Implementing a 30% threshold for municipalities would result in a negligible classification of areas as either low or high income due to the more homogenous economic conditions across the MAB. In contrast, the pronounced income disparities within Barcelona's neighbourhoods necessitate a broader threshold to accurately capture the varying economic realities, ensuring a more nuanced classification. Moreover, the methodology for the neighbourhoods aligns with the practises of the BCNROC, which utilises a 30% threshold. For the municipalities, the adaptation of a 20% threshold, despite being a novel approach not pre-established by existing studies, is pragmatically chosen to reflect the distinct economic uniformity of the MAB, ensuring the study's relevance and applicability

In Appendix I, tables displaying GDHI and DHI for each municipality in the MAB and for neighbourhoods within Barcelona are presented. These tables also categorise incomes as high, medium, or low.

2. Non-compliant cars

To gather data on the percentage of non-compliant cars in each municipality, the fleet of vehicles was obtained from IDESCAT in 2022. The data on the environmental levels of each vehicle in each municipality was obtained from the official website of the General Direction of Traffic (DGT, 2022). The reason the data from 2022 was utilised is because that is the only year from which data on the environmental levels of the vehicles in each municipality is provided.

The same data, but on a neighbourhood and territorial scale, was gathered from the dataset of the Barcelona Town Hall. Both the data from 2019 and 2021 was used in order to be able to compare the percentage of non-compliant cars at the beginning of the policy implementation and two years later (Ajuntament de Barcelona, 2019 & Ajuntament de Barcelona, 2021).

In terms of identifying vehicles that do not comply with regulations, the process involves examining the environmental labels assigned to each car across various municipalities and neighbourhoods. As previously noted, within the LEZ, four specific environmental labels are permitted: distinctive CERO, distinctive ECO, distinctive C, and distinctive B. The task of classifying non-compliant vehicles is straightforward. Cars lacking any of these environmental labels are prohibited from entering the LEZ as they fail to meet the necessary environmental standards. To obtain the percentage of non-compliant vehicles, the total number of non-compliant vehicles will be divided by the total number of vehicles in each unit of analysis and then multiplied by 100.

In Appendix I, a table showcasing the percentage of non-compliant cars for each unit of analysis is presented.

3. Public transport quality

In this study, aimed at evaluating the feasibility of transitioning from car to public transportation within the LEZ, a comprehensive analysis was conducted. This involved comparing the average travel times by both car and public transportation for each spatial unit to a strategically chosen

point within the LEZ, ‘Plaça de Catalunya’, which is found in the centre of the LEZ area. Choosing 'Plaça Catalunya' as the endpoint for assessing the time it takes to travel from each unit of analysis by public transport inherently biases the outcomes in favour of shorter travel times. As the city centre of Barcelona and a major public transport hub, Plaça Catalunya is exceptionally well-connected. Every mode of public transport, including metro, buses, and regional trains, converges here, significantly enhancing accessibility. This central location means that travel times to Plaça Catalunya are likely to be shorter and more direct compared to other destinations within the LEZ, reflecting the high density of public transport options available in this area. Consequently, this choice may not fully represent the variability in access times experienced by residents travelling to different parts of the LEZ.

The methodology for this comparison was influenced by Verbeek & Hincks (2022), who emphasised the significance of accessibility as conceptualised by da Schio et al. (2019). To accurately determine these average travel times, the Google Direction API was employed. Car travel times were calculated using historical data that reflected typical traffic conditions, while public transport times were based on official timetables. Finally, to assess public transport quality effectively, an 'additional or reduced travel time by public transport' metric was established. This was derived by deducting the average car travel time from the average public transport travel time, offering a clear comparative perspective.

In the case of the MAB, a key criterion was established: if the difference in travel time by public transport exceeds 10 minutes when compared to private transport, the public transport quality is deemed low; conversely, a difference of less than 10 minutes indicates high quality. For the neighbourhoods, a similar approach was used, but with a tighter threshold of 5 minutes. To facilitate the analysis of the correlation between income levels and public transport quality, a binary categorization system was adopted for each municipality and neighbourhood. In this system, a score of 1 represents good public transport quality, while a score of 0 indicates poor quality. This binary approach simplifies the process of correlating transport quality with income data, allowing for a more straightforward analysis.

In Appendix I, a table showcasing the time difference between travelling by private and public transport is displayed, along with the categorization of public transport quality for each MAB municipality and Barcelona neighbourhood.

4. **Households with newer cars**

To gather data on the percentage of households that have acquired a new car since the implementation of the LEZ policy in the neighbourhoods of Barcelona, the same databases used to find out the percentage of non-compliant cars were used. This indicator was calculated by subtracting the percentage of non-compliant cars in 2019 and 2021 to see if or how much it had decreased. By comparing the differences in the percentage of non-compliant cars in the years 2019 and 2021 in each neighbourhood, it can be assessed which neighbourhoods have made the biggest economic efforts to adapt to the LEZ emission standards. The reason why this indicator is only calculated at the neighbourhood level is because there is no available data on the environmental levels of the vehicles at the municipality lever other than from the year 2022, and therefore a comparison cannot be done.

In Appendix I, a table showcasing the non-compliant car percentage reduction in each neighbourhood of Barcelona is displayed.

3.4.2 Data Analysis – Statistical correlation analysis

To clarify the analysis of the LEZ policy's distributional effects, a targeted statistical correlation analysis was employed, focusing on specific relationships between the quantitative indicators from the collected data. Within the MAB, 36 units of analysis were identified, and for Barcelona's neighbourhoods, there were 73 units. For each of these units, four key indicators were considered. However, the correlation analysis specifically assessed the relationship between income levels (GDHI and DHI index) and the three other variables: the number of non-compliant cars, the quality of transport, and the percentage reduction in non-compliant cars. This focused approach allowed for a detailed examination of how income correlates with factors directly impacted by the LEZ policy, providing insight into the policy's distributional effects without analysing every possible combination of indicators. Following, a step-by-step guide to the correlation analysis is presented:

1. **Organise the data:**

The data was arranged in a tabular format where each row represents a unit of analysis (municipalities of the MAB and the neighbourhoods of Barcelona), and each column represents an indicator: GDHI/DHI per inhabitant, proportion of non-compliant cars, quality of public transport, households with newer cars). The table with the data displayed can be found in the appendix.

2. **Calculate Pearson correlations:**

To assess the distributional effects of the LEZ policy, Pearson correlation coefficients were calculated for specific pairs of indicators across each analysis unit. The Pearson correlation coefficient is a statistical measure that calculates the strength and direction of the linear relationship between two variables (Zou et al., 2003). This analysis, conducted using Python and Excel, focused on correlating the income level for both the municipalities within the MAB (GDHI index) and for Barcelona's neighbourhoods (DHI index) with the three other indicators. This approach produced five distinct correlations (table 3), pinpointing the relationship between income levels and LEZ policy-impacted factors. Moreover, a significance test will be calculated for each correlation. A significance test for Pearson correlations assesses whether the observed correlation between two variables significantly differs from zero in a population. This test indicates the probability that the observed correlation occurred by chance if there's no true correlation in the population. If the correlation is proven to be statistically significant, this suggests a meaningful relationship between the variables that is unlikely due to random variation alone.

Table 3. Correlations performed

UNITS OF ANALYSIS	CORRELATIONS
Municipalities of MAB (36)	Income – % non-compliant cars
	Income – Public transport quality

Neighbourhoods of Barcelona (73)	Income – % non-compliant cars
	Income – Public transport quality
	Income – Percentage reduction of non-compliant cars

3. **Interpret Results:**

To interpret the results, the correlation coefficients were analysed to understand the strength and direction of relationships between different pairs of indicators.

The correlation coefficient, denoted as 'r', is a statistical metric used to quantify the strength and direction of the relationship between two variables. This coefficient ranges from -1 to +1, with -1 representing a perfect negative correlation, +1 indicating a perfect positive correlation, and 0 signifying the absence of correlation. The magnitude of the coefficient is indicative of the strength of the relationship. A coefficient between -0.3 and +0.3 is generally classified as a weak correlation, implying a minimal association between the variables. In contrast, a moderate correlation is observed when the coefficient ranges between -0.3 and -0.7 or +0.3 and +0.7, denoting a more substantial but not exceedingly tight relationship. Finally, a strong correlation is characterised by coefficients from -0.7 to -1.0 or +0.7 to +1.0, suggesting a significant, closely-knit relationship where changes in one variable are closely associated with changes in the other. It is crucial, however, to acknowledge that correlation does not equate to causation; a high degree of correlation does not inherently imply that one variable causally influences the other, as there could be other contributing factors or variables at play (Zou et al., 2003).

Moreover, the significance test for each correlation's coefficient was also analysed. This test calculates a p-value, which indicates the probability that the observed correlation occurred by chance if there's no true correlation in the population. If the p-value is below a predetermined threshold (commonly 0.05), the correlation is considered statistically significant, suggesting a meaningful relationship between the variables that is unlikely due to random variation alone (Zou et al., 2003).

The fact that this study works with aggregated figures, such as averages at the municipal or neighbourhood' level, inherently involves a level of abstraction from individual data points. This approach can mask variations within each unit of analysis and potentially overlook the nuanced experiences of smaller groups or individuals. Working with aggregated figures facilitates the analysis of broader trends and patterns, offering valuable insights into the general impacts of policies like the LEZ. However, it's crucial to acknowledge the limitations. Specifically, aggregation may smooth out disparities and unique circumstances, leading to conclusions that represent the average scenario but not the diversity of experiences within each area (Raghunathan et al., 2003).

4. **Visualize Results:**

Finally, the results of the analysis are presented in a visual way to provide a more intuitive understanding of the relationships between the indicators.

This approach endeavours to provide insights into the underlying patterns and potential causative linkages that may inform future research directions or policy formulations.

3.5 Qualitative surveys

In the second empirical phase of data collection, a qualitative survey was conducted within two distinct neighbourhoods of Barcelona: Pedralbes and Ciutat Meridiana. Qualitative surveys, although often underused, can complement traditional qualitative methods. They bring depth and insight into participants' experiences and perspectives, making them a valuable research tool (Braun et al., 2020). Therefore, this methodological choice was made in order to further analyse the varied experiences and adaptation strategies to the LEZ policy beyond a quantitative lens. Pedralbes and Ciutat Meridiana were selected based on the significance of examining these neighbourhoods due to their poor public transport quality and contrasting socioeconomic statuses. Pedralbes, known for its affluence, and Ciutat Meridiana, identified as economically challenged, offered a unique comparative perspective on the impacts of LEZ policy, reflecting a broad spectrum of urban living conditions and adaptation capabilities. This comparative analysis aimed to uncover the nuanced distributional effects of LEZ policy within Barcelona, providing critical insights into the socio-economic and transportation-related challenges faced by residents. The reasoning behind choosing these two neighbourhoods will be further developed in the results of the survey section (4.2), as well as a detailed description and contextualization of the neighbourhoods.

3.5.1 Data Collection

The data collection process for the survey, which forms the second part of the methodological approach, involved a detailed and methodical approach to gather insights on the experiences and adaptations to the LEZ policy. This process began with the survey design. A comprehensive survey was developed to capture a wide range of information about the population's experiences due to the LEZ policy, their adaptations to it, and their satisfaction with the policy. Five key themes were targeted within 15 questions to paint a comprehensive picture of the policy's multifaceted effects. The survey begins by assessing the **level of awareness and understanding** that individuals hold about the LEZ, probing into their grasp of the policy's objectives and the specifics of its enforcement. The narrative then shifts to the **social and community effects**, exploring how the LEZ has influenced social dynamics, community engagement, and potential social divides within affected neighbourhoods. **Economic impacts** are scrutinised next, with the survey seeking insights into how the policy has altered financial landscapes for individuals and households, particularly in terms of transportation costs and vehicle ownership. **Adaptation strategies** form another critical component of the investigation, revealing the various ways people have adjusted their daily lives and routines in response to the LEZ, highlighting both challenges and innovative coping mechanisms. The survey culminates in an evaluation of **overall satisfaction with the LEZ policy**, capturing a broad spectrum of sentiments ranging from approval to dissent. The full survey design can be found in Appendix II.

Following the survey design, a sampling strategy was implemented. The focus was on residents living within Pedralbes and Ciutat Meridiana. In the hopes of achieving a representative sample, participants were randomly selected from these neighbourhoods. However, due to the relatively low participation, it cannot be stated that the final population sample is fully representative. Although there were only 24 respondents in total (14 from Pedralbes and 10 from Ciutat

Meridiana), the responses provided valuable insights, as very clear patterns of experiences and adaptation to the LEZ policies were identified.

The final step was the survey distribution. The primary method for administering the survey was face-to-face interaction, which allowed for more in-depth responses. Additionally, the survey was made available online via a QR code, offering an alternative mode of participation. Participants received clear instructions on how to complete the survey, ensuring the process was straightforward and efficient.

3.5.2 Data analysis

The data analysis of the qualitative surveys consists of three main parts.

First, a **data extraction** of the responses was carried out to provide simple and straightforward descriptions of the answers provided by the participants for each question. Presenting the data in terms of percentages and counts provides a clear, quantitative overview of the survey results and allows the researcher and the reader to have a clear knowledge of the outcome of the survey. Moreover, this first description of the answers sets a baseline for a deeper qualitative analysis. Understanding the percentages and the overall distribution of responses helps to contextualise the quotes and narratives extracted from open-ended questions.

The second step in the data analysis of the qualitative survey consisted of conducting a **thematic analysis**. A thematic analysis is known as the process of exploring through a data collection to find, examine, and report recurring patterns (Braun and Clarke, 2006). This technique is used to study qualitative data. It's a way to describe facts, but in the process of choosing codes and creating themes, interpretation is also involved. According to Kiger & Vapito (2020), a distinguishing characteristic of a thematic analysis is its flexibility to be used for a wide range of study questions, designs, and sample sizes, which makes it a suitable method to analyse the data from this thesis's qualitative surveys. Moreover, Braun and Clarke (2012 state that theme analysis is a suitable and effective technique to employ when attempting to comprehend a collection of experiences, ideas, or behaviours throughout a data set.

The conduct of this thematic analysis was done based on the six steps outlined by Braun and Clarke (2006).

- Familiarization with Data:

  The first step in any thematical analysis consists of getting familiar with the data by thoroughly reading the responses to gain a deep understanding of the data in order to identify initial ideas and patterns. This was done in the previous step, when describing the survey results.

- Generating code:

  The data was coded by identifying significant or recurrent responses, sentiments, or phrases across both neighbourhoods in order to capture key concepts related to awareness, impacts, satisfaction, and adaptations to the LEZ policy. The coding was done in a deductive way, guided by the theoretical and conceptual framework of the thesis as well as the pre-established themes of the survey. No specific programme was used for the coding step; it was done manually. The codes are displayed in the result section.

- Searching for themes:

The third step that usually follows this type of thematic analysis consists of grouping the codes into potential themes that represent broader patterns in the data. A theme is a 'patterned response or meaning' (Braun and Clarke, 2006) derived from the data that informs the research question. However, in this case, the themes were predetermined by the design of the survey, so what was done was classify each code generated in the previous step within each existing theme.

- Reviewing Themes:

The fourth step consisted of checking if the themes worked in relation to the coded extracts and the entire dataset. A few preliminary themes were split, combined, and even discarded if they did not have enough data to support them or did not contribute to understanding the impacts of the LEZ policy in both neighbourhoods.

- Defining and Naming Themes:

Once the themes were fully identified and named, the fifth step consisted of writing a small description of each theme, explaining what it captures and how it relates to the research question.

- Writing the analysis:

Finally, the last step of the thematic analysis was to write up the final analysis and description of the findings. The analysis tells the story of how the LEZ policy has been perceived and its effects on residents in Pedralbes and Ciutat Meridiana, supported by direct evidence from the survey data. This was done using both narrative descriptions and representative data extracts, such as direct quotations from participants.

Finally, an **interpretation** of the results and thematic analysis were conducted to explain to the reader how the LEZ policy in Barcelona has affected the two different neighbourhoods.

3.6 Validation step – Semi structured interviews with experts

Following the execution of the two empirical data analysis steps, a critical validation step was undertaken in order to answer sub-question 4, which consisted of discussing the results of the prior statistical correlation analysis and qualitative surveys with mobility experts.

This process not only ensures that the results are thoroughly examined and validated by professionals in the field, but it also adds a significant layer of credibility and insight to the study's conclusions. The engagement with experts, who possess specialised knowledge in urban mobility dynamics, is particularly relevant for the examination of the distributional effects of the LEZ policy. These experts contribute to a more nuanced understanding of the policy's impact on diverse socio-economic groups, offering insights into potential behavioural shifts, specific mobility patterns, and unforeseen consequences of the LEZ policy. By integrating these expert opinions, the thesis bridges the gap between quantitative data and real-world complexities. This approach enhances the study's scholarly contribution, particularly in the discourse on distributional justice in the context of LEZ policies, as outlined by Bogner et al. (2009). This

collaboration not only fortifies the robustness and reliability of the thesis but also enriches its overall academic value.

3.6.1 Data Collection

For the validation step via interviews with experts, gathering relevant and reliable data was crucial to ensuring the robustness and credibility of the study. The first step involved identifying and engaging with mobility experts who possess specialised insights into urban mobility dynamics and the impact of LEZs (LEZs) on socio-economic groups. The goal was to contact 3–5 experts. It was intended to include a mix of experts that are more familiar with the particular case of Barcelona as well as general experts on the topic of mobility and accessibility from other backgrounds. Four experts were identified, contacted, and interviewed.

Table 4. Mobility experts' description

Expert	Affiliation	Role / Specialization	Notable Contributions / Projects
Núria Pérez Sans	Institut Metròpoli	Head of the Mobility area	- Developed applied research studies on population's behaviour and needs in mobility - Planning and management of metropolitan and urban mobility - Processing and analysis of transport databases - Participating in the drafting of documents and studies for the Metropolitan Urban Mobility Plan of the MAB - Co-authored the 2022 report "Analysis of the socio-economic impact in the territorial area of the Zona de Baixes Emissions Rondes de Barcelona"
David Andrés Agromedo	Institut Metròpoli	Mobility technician	- Worked in mobility planning, specializing in externalities: air pollution, noise, and social cohesion - Part of the Metropolitan Urban Mobility Plan of the AMB - Studies on the social perspective in mobility - Co-authored the 2022 report "Analysis of the socio-economic impact in the territorial area of the Zona de Baixes Emissions Rondes de Barcelona"

Prof. dr. ir. Dick Ettema	Utrecht University	Professor of Urban Accessibility and Social Inclusion	- Research on how changes in population, economy, society, and technology impact cities' and urban regions' accessibility - Studies the impact on people's daily activities, travel habits, social inclusion, health, and the sustainability of transportation
Dr. Toon Meelen	Utrecht University	Assistant professor in Innovation Studies	- Research on innovations in transport, energy and housing. - Interdisciplinary research that builds on insights from the fields of Sustainability Transitions, Innovation Studies, and Political Economy.

A semi-structured interview was drafted, which is a qualitative research method that uses a pre-designed interview guide with a mix of open-ended and specific questions. This approach allowed for in-depth discussions while providing the flexibility to explore new topics that emerged during the interview. It facilitated a focused yet conversational exploration of the topic at hand while allowing for the gathering of nuanced insights from each expert depending on their background and experiences (Adeoye-Olatunde & Olenik, 2021). The full interview can be found in Appendix III. The questions posed during these interviews aimed to elicit expert opinions on the results of the statistical correlation analysis and the results of the qualitative survey, as well as discuss behavioural shifts, specific mobility patterns, and unforeseen consequences of the LEZ policy. The main components on the interview are the following: general knowledge on LEZ policies, reflection on statistical correlation analysis results, reflections on survey results, additional monitoring of distributional effects, personal opinions on LEZ policies; and expert opinions and recommendations on enhancing equality

3.6.2 Data analysis

The data from the semi-structured interviews with experts was analysed manually, focusing on a thematic exploration rather than employing a structured coding process. This approach was chosen to ensure flexibility in identifying and understanding the complex nuances within the experts' discussions. The analysis concentrated on the key components of the interview, which are mentioned in the previous section.

By concentrating on these key components, the analysis aimed to construct a comprehensive view of the experts' opinions on the multifaceted impacts of LEZ policies in Barcelona. This approach allowed for the identification of consensus points amongst the experts on the research methodology and validity of the findings, as well as their divergent views, and the identification of the expert's educated suggestions on how to improve the policy. The analysis was conducted through a detailed review of interview transcripts, with attention to both explicit statements and the underlying assumptions and values expressed by the experts.

3.7 Ethical considerations

The research undertaken in this thesis on the distributional effects of LEZ policies in Barcelona was guided by a robust ethical framework to ensure integrity, respect, and responsibility throughout the study. Research ethics were essential to the process and involved every step of the investigation, including choosing a topic, collecting and analysing data, and the dissemination of study findings (Pietilä et al., 2019).

The focus of this research is the distributional effects of LEZ, which is a sensitive topic as it involves analysing the experiences of vulnerable groups. To avoid any harm or offence to the participants of both the qualitative surveys and the semi-structured interview, as well as any potential readers, the following actions were undertaken based on equity frameworks extracted from (Pietilä et al., 2019 & Shaw & Stalkar, 2018).

Autonomy and Informed Consent: Prior to conducting the surveys or the interview's, informed consent was obtained from all participants. This process involved clearly explaining the purpose of the study, how the data would be used, and the participants' rights, including their right to withdraw from the study at any time without penalty.

Anonymity and Confidentiality: To protect the identities of the survey participants and maintain confidentiality, no identifying information was included in the survey design. This measure was crucial to fostering an environment where participants felt comfortable sharing their insights openly. In the case of the experts interviewed for the validation step, spoken consent to use their names in the report was asked and recorded, to which they all agreed.

Sensitivity and Respect: The research topics covered somewhat sensitive issues related to public policy and its impacts on communities. Throughout the data collection and analysis phases, care was taken to approach these topics with respect and sensitivity towards the participants' perspectives and the broader societal context.

Bias and Objectivity: The research was conducted with an awareness of the potential for bias. Efforts were made to approach the analysis objectively, considering multiple viewpoints and acknowledging any personal biases that might influence the interpretation of the data.

Impact and Dissemination: Ethical considerations were also extended to the potential impact of the research findings. The research results and findings are intended to be presented in a way that contributes constructively to the discourse on LEZ policies and their implications, avoiding misinterpretation.

This ethical framework underscores the commitment to conducting rigorous and responsible research. It reflects an understanding of the ethical complexities inherent in studying public policy interventions and their effects on diverse populations.

4 Results

In the following section, the results for both parts of the analytical framework—the statistical correlation analysis and the qualitative surveys—are presented and interpreted in order to answer sub-question 3. Then, the four interviews with mobility experts are described and analysed, answering sub-question 4.

4.1 Statistical correlation analysis results

The chapter presents the results of the statistical analysis conducted to explore the dynamics between various indicators across the municipalities within the MAB neighbourhoods of Barcelona. Following the outlined methodology, the analysis aims to study the correlation between the GDHI indexes of the 36 municipalities of the MAB and the HDI of the 73 neighbourhoods in Barcelona with specific indicators. These indicators include the percentage (%) of non-compliant cars, public transport quality, and the percentage reduction of non-compliant cars since the implementation of the regulations. The latter indicator is only examined for the neighbourhoods in Barcelona due to the unavailability of data for the municipalities in the MAB. Table 4, found in section3.4.2 of the methodology chapter, provides a summary of the correlation studies conducted.

This analytical approach offers insights into how these indicators are influenced by the socio-economic and environmental situations of the corresponding neighbourhoods and municipalities, highlighting their impact on the implementation of relevant policies.

The section is structured into two parts: first, presenting the results of the correlation analysis for the municipalities of the MAB, followed by the results for the neighbourhoods in Barcelona. The outcomes of the correlation analysis are then examined in detail and subsequently discussed.

4.1.1 Descriptive statistics of each indicator

Before diving into the findings of each correlation, an overview of the descriptive statistics for each of the variables is provided.

Income indicator: MAB municipalities GDHI & Barcelona neighbourhoods DHI

The first indicator is examining the GDHI for each municipality within the MAB and the DHI for each neighbourhood in Barcelona. To establish a classification of the municipalities and the neighbourhoods based on income, the average index in Catalonia (100) and Barcelona (1.00) were respectively, was described in the methodology section (3.4).

Following this methodology, municipalities and neighbourhoods were categorised into low, medium, and high-income groups. In the MAB, 2 municipalities were classified as having low income, 31 municipalities as having medium income, and 3 municipalities as having high income (Figure 6). In Barcelona, 24 neighbourhoods were classified as low income, 39 neighbourhoods as medium income, and 10 neighbourhoods as high income (Figure 7). A detailed list of which municipalities and neighbourhoods are qualified as low, medium, and high income is provided in the annex, offering an overview of the income distribution across the MAB and Barcelona.

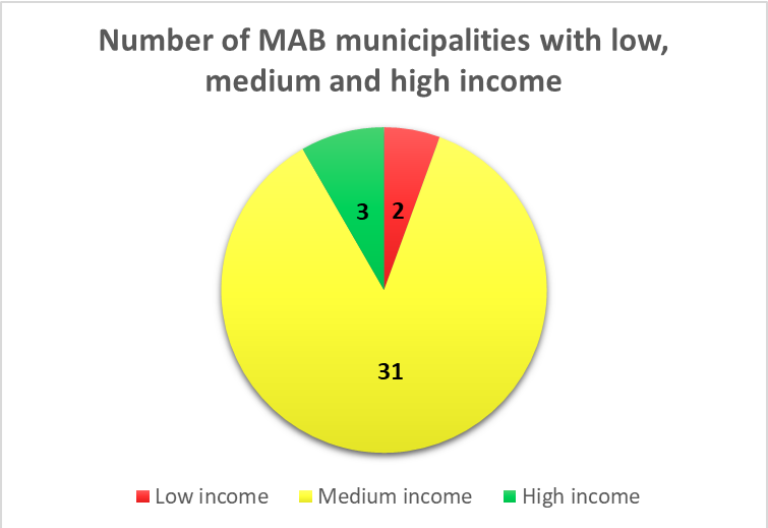

Figure 6. Low, medium and high-income MAB municipalities

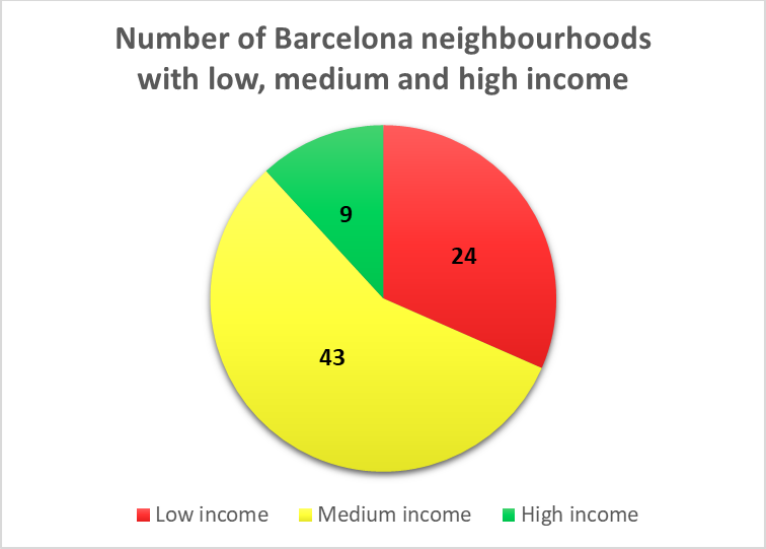

Figure 7. Low, medium and high-income neighbourhoods

Non-compliant cars indicator

The "non-compliant cars" variable represents the percentage of cars within each municipality and neighbourhood that do not meet the LEZ regulatory standards and criteria. The data indicates a variation in compliance levels across different municipalities and neighbourhoods.

In the municipalities within the MAB, the recorded percentages of non-compliant cars range from a minimum of 16% in La Palma de Cervelló to a maximum of 30% in Badia del Vallès. For the neighbourhoods of Barcelona, the lowest recorded percentage of non-compliant cars is 16.82% in Diagonal Mar I el Front Marítim del Poblenou, while the highest percentage is 38.87% in Torre Baró.

A list with the percentage of non-compliant cars for each municipality and neighbourhood can be found in the appendix.

Public transport quality indicator

The assessment of public transport quality across the MAB municipalities reveals a notable variation. According to the evaluation criteria outlined in Section 3.4, 14 of the 36 municipalities and only 12 out of 73 neighbourhoods are categorised as having "poor" transport quality. This means that more than half of the municipalities in the MAB and most of the neighbourhoods in Barcelona do not have significant added time for travelling by public transport rather than with a private vehicle, or might even have a shorter average travel time by public transport than the average travel time by car. This is noteworthy because, unlike car travel times, which presuppose the availability of a car from origin to destination, computed journey times by public transportation almost invariably include a portion of travel time spent on foot to and from a station or stop (Verbeek & Hincks, 2022). For a comprehensive understanding of which municipalities are deemed to have "good" versus "poor" transport quality, readers are directed to the detailed list provided in Appendix I.

Percentage reduction of non-compliant cars indicator

Lastly, the analysis also considered the percentage reduction of non-compliant cars in the neighbourhoods of Barcelona. This variable reflects the change in the proportion of non-compliant cars from the year 2019 to 2021 within each neighbourhood. The smallest percentage reduction of non-compliant cars takes place in the neighbourhood of la Marina del Prat Vermell – AEI Zona Franca, with only 0.55%. On the other hand, the biggest percentage reduction takes place in Baró de Viver, with a notable decrease of 10.12%. Once again, the full list of non-compliant percentage reductions in each neighbourhood can be found in the annex.

4.1.2 Statistical Pearson correlation analysis results

After providing an overview of the descriptive statistics for the chosen variables, the analysis now progresses to examining the correlations between them, which are summarised in Table 5. This phase is pivotal in identifying and understanding the relationships that exist between these four variables of interest.

By employing correlation analysis, the extent and nature of the associations among these variables are uncovered, whether they move in tandem (positive correlation), in opposite directions (negative correlation), or exhibit no discernible relationship (no correlation) is uncovered. This step enriches the understanding of the data's interdependencies.

Table 5. Coefficients of each correlation analysis performed

Pearson correlation coefficients	Municipalities AMB	Neighbourhoods of Barcelona
Income & non-compliant cars	-0.5	-0.4632
Income & public transport quality	-0.2074	0.1668
Income & Percentage reduction of non-compliant cars		-0.6265

Correlation 1: GDHI index and non-compliant cars within the MAB municipalities

The negative correlation coefficient of -0.500 between the GDHI of the AMB municipalities and the percentage of non-compliant cars in LEZ standards in Barcelona suggests a moderate inverse relationship between the economic prosperity of the municipalities and the number of non-compliant vehicles. In practical terms, as the GDHI increases, the proportion of non-compliant vehicles tends to decrease, and vice versa. This implies that areas with higher economic well-being are more likely to have a lower percentage of vehicles that do not meet the specified emission standards set by the LEZ policy.

Figure 8 shows the percentage of non-compliant cars for every value of the GDHI of the municipalities. Each dot represents a municipality within the MAB. The GDHI per inhabitant is plotted on the x-axis, indicating a spread of income levels across different municipalities relative to the Catalonia average. The percentage of non-compliant cars is plotted on the y-axis.

Looking at the plot, it can be seen that as the GDHI increases, the proportion of non-compliant vehicles tends to decrease. This implies that areas with higher economic well-being are more likely to have a lower percentage of vehicles that do not meet the specified emission standards set by the LEZ policy.

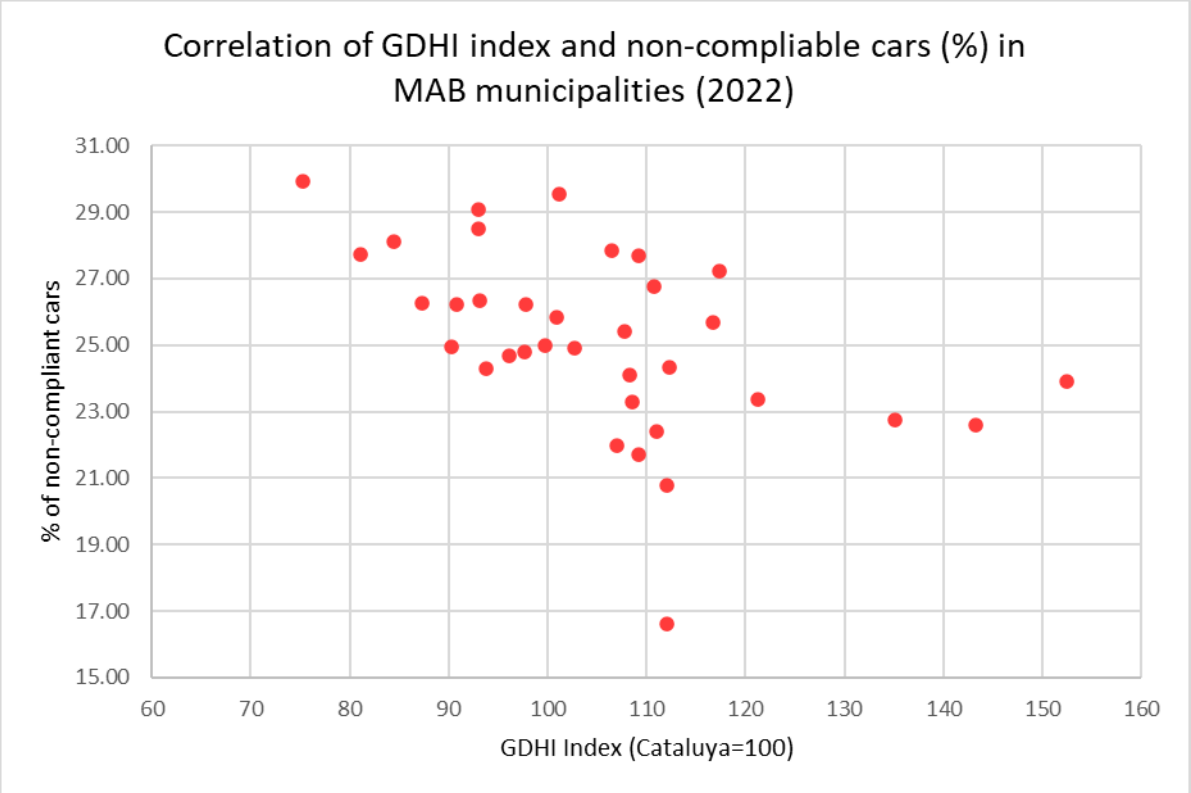

Figure 8. Scatter plot of the percentage of non-compliant cars vs. GDHI values of the municipalities.

Notably, a substantial number of municipalities with a per capita GDHI below or around average (100) exhibit a prevalence of 25% to 30% of non-compliant cars, representing the higher end of non-compliance rates. On the other hand, municipalities with a lower percentage of non-compliant cars, typically less than 25%, demonstrate an above-average GDHI per capita. An exceptional case within this trend is the municipality of La Palma de Cervelló, which, despite not having a markedly high GDHI index, shows the lowest proportion of non-compliant cars,

distinguishing it as a notable outlier in the dataset. There is no known reason behind this outlier. Nonetheless, this pattern underscores the likely association between economic prosperity and vehicular compliance, revealing a concentration of higher non-compliance rates in economically challenged municipalities and a lower incidence in more affluent areas within the AMB region.

While the negative correlation of -0.5 indicates a moderate inverse relationship between the GDHI per inhabitant and the percentage of non-compliant cars in the municipalities of the MAB, a test for significance was conducted and yielded a p-value of under 0.05, affirming that the correlation is statistically significant. This finding strengthens the argument that there is a notable association between these variables, though it must be interpreted with caution. It's crucial to understand that correlation does not imply causation (Zou et al., 2003). The observed trend—where wealthier municipalities appear to have a lower percentage of non-compliant cars—does not necessarily mean that higher income directly causes better compliance with vehicle regulations. There could be various underlying factors contributing to this correlation that are not captured in this study. However, while it is not definitive, the negative correlation and its statistical significance suggest that income may influence households' ability and likelihood to own compliant vehicles, among other potential factors.

Correlation 2: DHI index and non-compliant cars within Barcelona neighbourhoods

An analysis of the neighbourhoods within Barcelona uncovers a negative correlation coefficient of -0.4632, again indicating a moderate inverse relationship between the DHI and the percentage of non-compliant cars in each neighbourhood. This analysis was tested for statistical significance, and the results were under 0.05, confirming the negative correlation is statistically significant. This negative correlation suggests a moderate inverse relationship between the economic prosperity of the neighbourhoods and the prevalence of non-compliant vehicles, which implies that neighbourhoods with higher economic prosperity may exhibit a higher percentage of LEZ-compliant vehicles.

The scatter plot presented in figure 9 provides once again a visual representation of the correlation between the DHI in Barcelona neighbourhoods and the percentage of non-compliant cars. In figure 2, the DHI per inhabitant is plotted on the x-axis, the percentage of non-compliant cars is plotted on the y-axis, and each dot represents a neighbourhood within Barcelona. It can clearly be seen that the neighbourhoods with the highest percentage of non-compliant cars are the ones with the lowest GDHI per capita. However, there is once again a clear outlier that can be easily spotted on the plot. The neighbourhood of Sant Pere, Santa Caterina i la Ribera, although having a DHI index of 0.81 has the second lowest percentage of non-compliant cars.

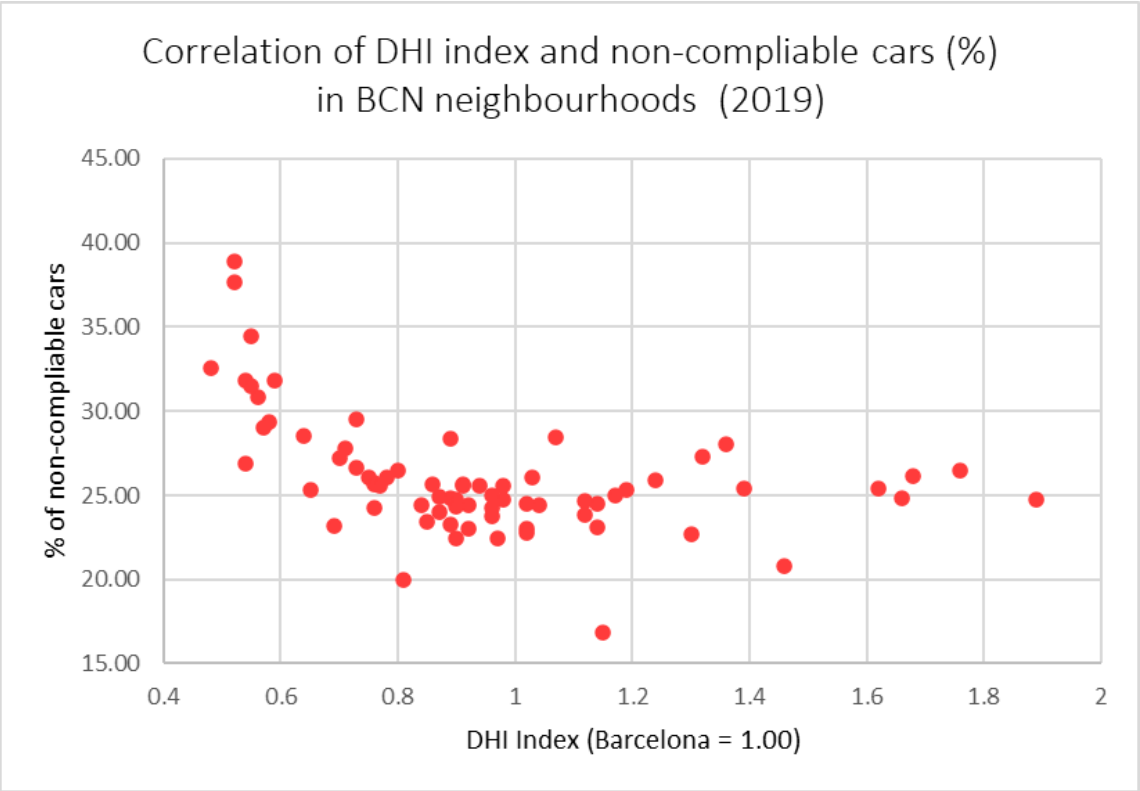

Figure 9. Scatter plot of the percentage of non-compliant cars vs. DHI values of the neighbourhoods in Barcelona.

The slightly stronger correlation in municipalities (-0.500) compared to neighbourhoods (-0.4632) suggests that this inverse relationship may be slightly more pronounced at the municipality level. However, the difference is relatively small, indicating that the trend is somewhat consistent across both geographical levels. In both cases, these correlations suggest that higher-income areas, whether at the municipality or neighbourhood level, tend to have fewer non-compliant cars.

Correlation 3: GDHI index and public transport quality within the MAB municipalities

The third correlation that was calculated is between the GDHI index and the public transport quality of each municipality in the MAB. The correlation coefficient of -0.2074 indicates a very weak but discernible negative association. This analysis was tested for significance, and with a p-value over 0.05, the correlation is deemed not statistically significant. This lack of statistical significance suggests that the observed weak negative association between GDHI and public transport quality should be interpreted with caution. It implies that, while there appears to be a slight tendency for municipalities with higher GDHI to report a marginally lower quality of public transport (or vice versa), this relationship is not robust enough to be considered reliable. The insignificance of the correlation further suggests that factors not accounted for in this analysis likely have a greater influence on public transport quality. Therefore, this weak correlation underscores that income levels alone cannot be considered a reliable predictor of public transport quality in the MAB municipalities, highlighting the complexity of factors that determine the quality of public transportation services.

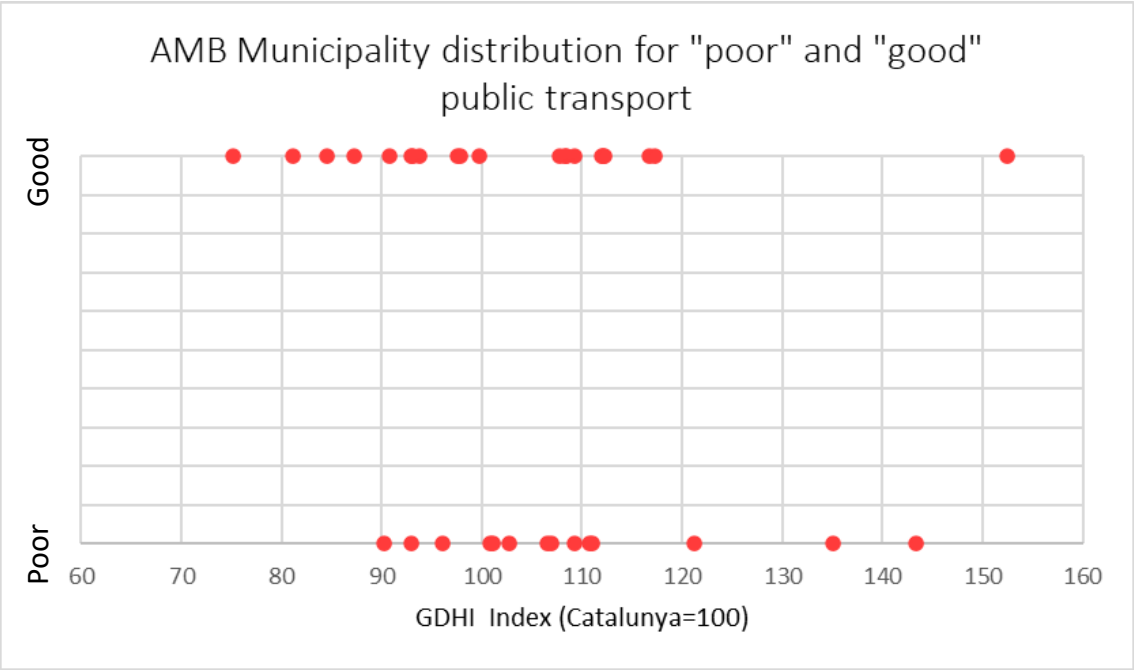

Figure 10. Scatter plot of municipalities classified with "good" and "poor" public transport quality

In the graph presented in Figure 10, it can be seen that, for the most part, the municipalities with poor public transport quality are municipalities with a medium level of income. On the other hand, all municipalities with a GDHI index lower than 90 are qualified as having good public transport quality. Moreover, a box plot presented in Figure 11 illustrates the distribution of GDHI across municipalities MAB, categorised by the quality of public transport. The orange line inside each box represents the median GDHI, which is the midpoint of the data, where half of the municipalities have a higher GDHI and half have a lower GDHI. The length of each box represents the interquartile range (IQR), which encompasses the middle 50% of the data for each category. From the plot, it can be seen that municipalities categorised as "Good Transport" have a more compact IQR, suggesting less variability in GDHI among them. In contrast, municipalities with "poor transport" show a greater spread of GDHI, as indicated by the longer box and whiskers, which are the lines extending vertically from the boxes. The whiskers indicate the variability outside the upper and lower quartiles, showing the range of the data excluding outliers. Finally, the outliers in both categories suggest that there are municipalities with particularly high GDHI values with both good and poor public transport, well above the median for that group.

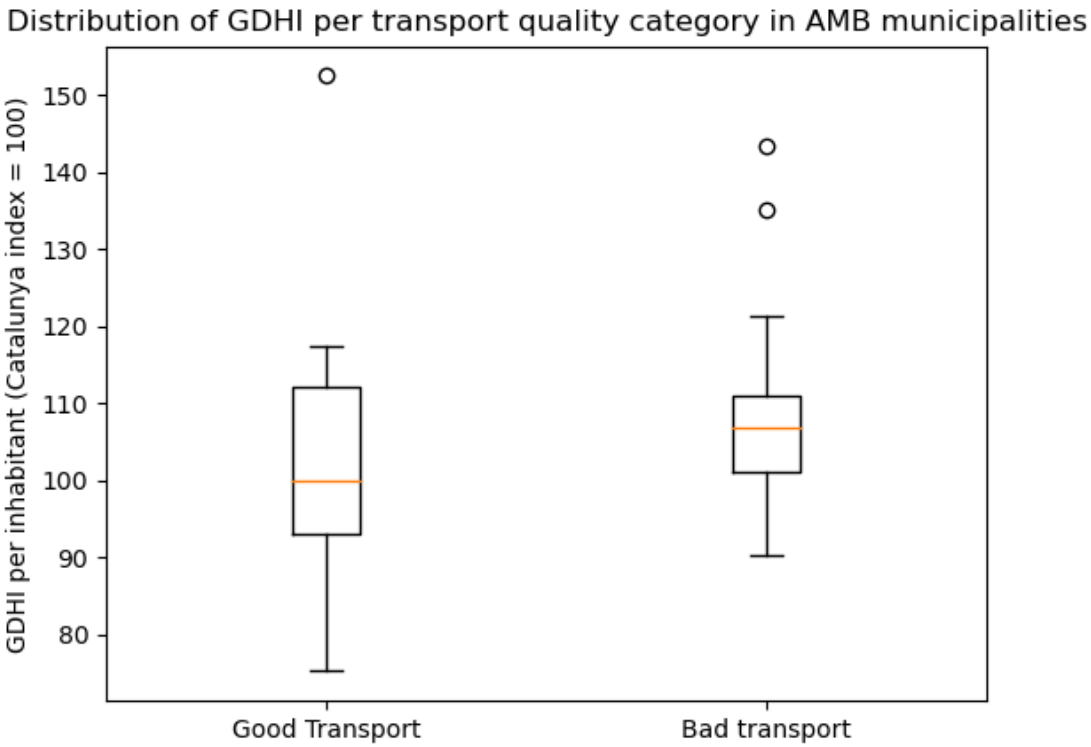

Figure 11. Box plot of the distribution of GDHI per transport public category in the neighbourhoods of Barcelona

Correlation 4: Transport quality with DHI index within Barcelona neighbourhoods

The positive but very weak correlation coefficient of +0.1668 between the quality of public transportation and the DHI within the neighbourhoods of Barcelona implies, at first glance, that lower DHI neighbourhoods are associated with a slightly better public transport quality. Conversely, higher DHI areas may exhibit a relatively less favourable perception. However, this analysis was once again tested for significance, and with a p-value over 0.05, the correlation is deemed not statistically significant. Therefore, just like with the previous correlation, this information should be taken with a grain of salt. Some important aspects should be taken into consideration when interpreting the results of this correlation. On one hand, it is important to keep in mind that the number of neighbourhoods with poor transport quality is really low (12 out of 73) compared to the number of neighbourhoods with good public transport quality. This imbalance can significantly affect the correlation. When the majority of data points belong to one category (in this case, good public transport), they can dominate the trend seen in the correlation coefficient (wang, et al., 2009; Lai et al., 2019). Moreover, it's essential to consider the distribution of the data points in the scatter plot presented in Figure 12. The graph shows that most neighbourhoods with bad PT are clustered in the lower half of the DHI index. However, because there are relatively few of them, their influence on the overall correlation is limited. If the numerous neighbourhoods with good public transport cover a wide range of DHI, as can be seen in the box plot displayed in figure 13, but are generally skewed towards the lower end, they could create a weak positive correlation. Moreover, the existence of outliers could also be influencing the positive correlation.

Therefore, given the sample imbalance and the weak correlation, the interpretation should be approached cautiously and understood that, just like with municipalities, income alone is not a

reliable predictor of public transport quality in Barcelona neighbourhoods. A more in-depth analysis, potentially involving more granular data or different statistical methods (like regression analysis controlling for other variables), might be required to understand the nuances of the relationship between PT quality and neighbourhood income levels.

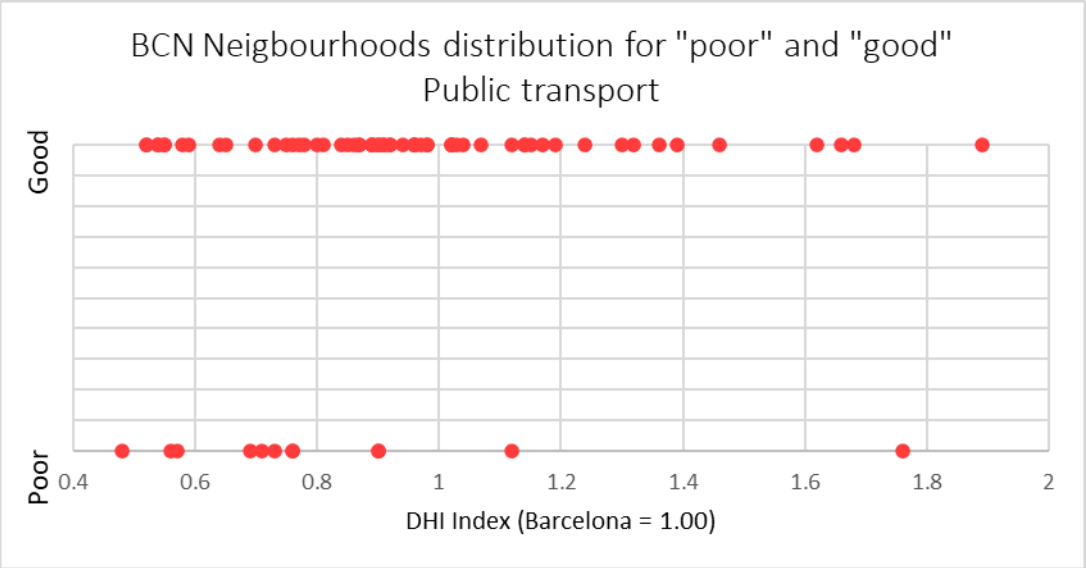

Figure 12. Scatter plot of neighbourhoods classified with "good" and "poor" public transport quality

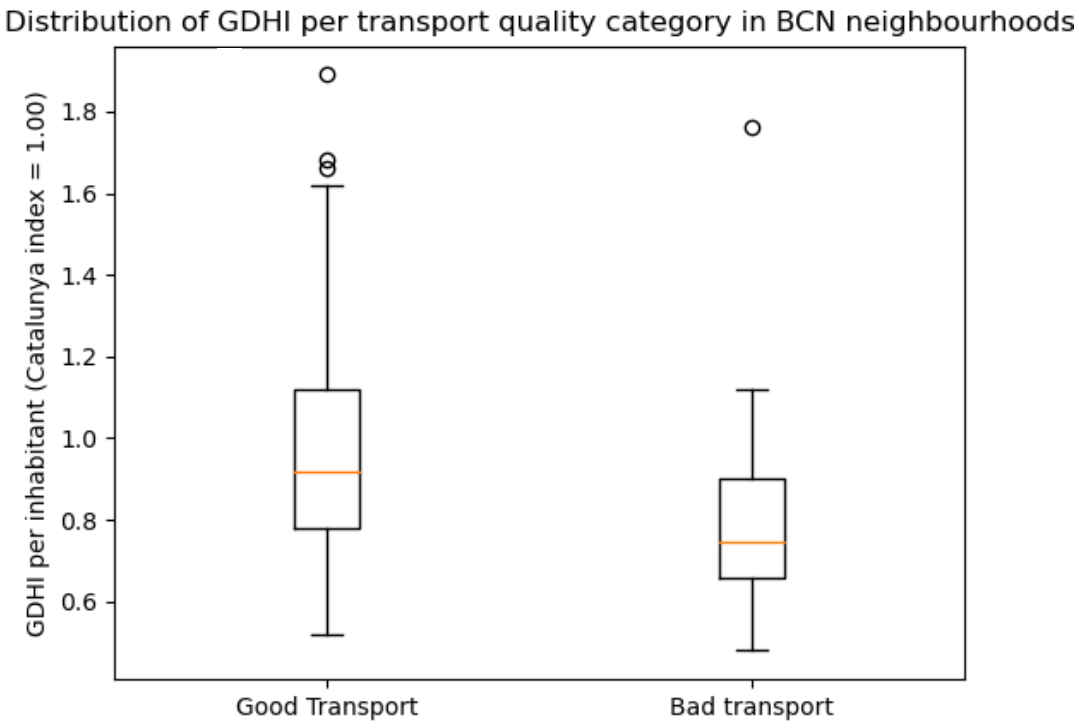

Figure 13. Box plot of the distribution of DHI per transport public category in the neighbourhoods of Barcelona

Correlation 5. DHI index and percentage reduction of on-compliant cars in the neighbourhoods of Barcelona

The final correlation explored was between the DHI index and the reduction percentage of non-compliant vehicles across Barcelona's neighbourhoods, revealing a moderate negative

correlation of -0.6265. This coefficient indicates an inverse relationship: as economic prosperity in a neighbourhood increases, the percentage of non-compliant cars decreases. Moreover, the significance test for this correlation was conducted and yielded a p-value of under 0.05, affirming that the correlation is statistically significant. This trend is vividly illustrated in the scatter plot of Figure 14, where each point signifies a distinct neighbourhood. A clear pattern emerges from the graph, showing neighbourhoods with a lower DHI index experiencing a more substantial reduction in non-compliant cars, albeit with some notable exceptions that deviate from this trend. For instance, la Marina del Prat Vermell (AEI Zona Franca), which recorded the smallest reduction in non-compliant vehicles, has a DHI index of 0.56. Conversely, Sant Pere, Santa Caterina, and Ribera, with a DHI index of 0.81, saw the second-smallest reduction. The anomaly of Marina del Prat Vermell-AAEI Zona Franca can be attributed to its exclusion from the LEZ zone. In contrast, the minimal change in Sant Pere, Santa Caterina, and Ribera could be due to its already low baseline of non-compliant cars, compounded by its central location and excellent public transportation options, reducing the urgency for residents to switch to compliant vehicles.

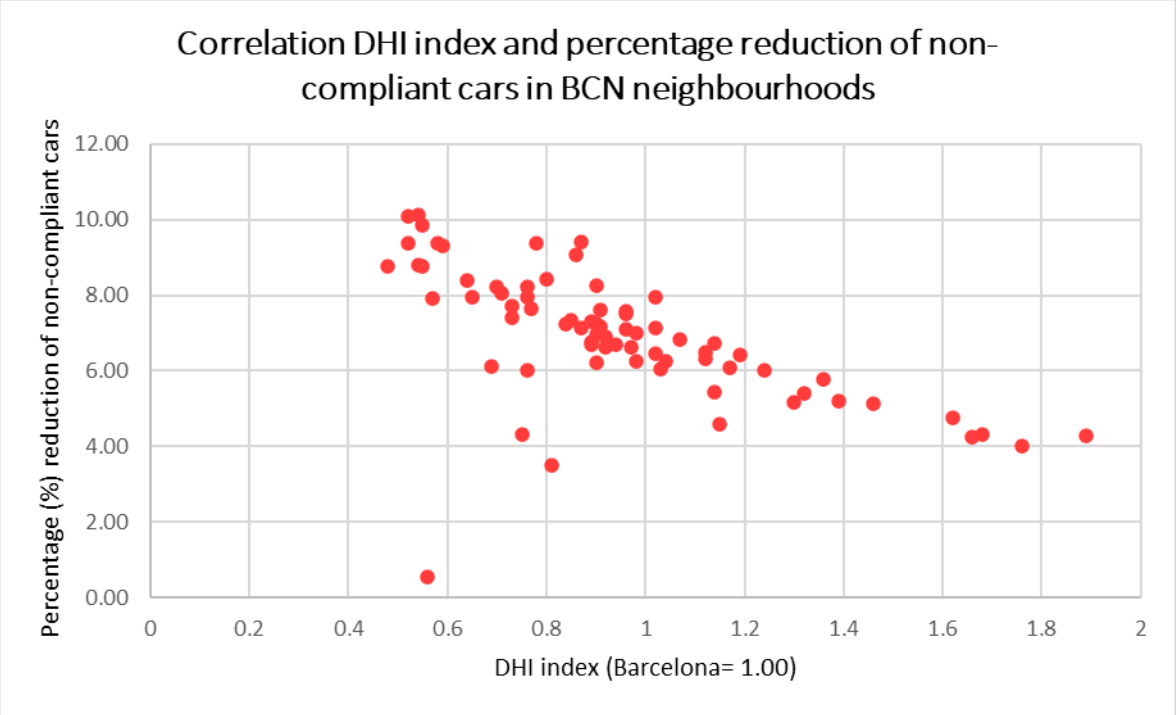

Figure 14. Scatter plot of the percentage reduction of non-compliant vehicles vs DHI values in the neighbourhoods of Barcelona

The overarching trend unveiled by this correlation likely stems from the initial higher prevalence of non-compliant cars in lower-income neighbourhoods at the LEZ policy's inception, prompting a more pronounced shift towards compliant vehicles. Meanwhile, more affluent neighbourhoods, already having fewer non-compliant cars, exhibited a less noticeable reduction post-policy implementation. This disparity suggests that the economic burden of transitioning to compliant vehicles has disproportionately affected lower-income neighbourhoods, highlighting the socio-economic implications of environmental policies like the LEZ.

4.1.3 Interpretation and insights

The statistical correlation analysis conducted in Section 4.1 of the thesis provides a nuanced understanding of the distributional effects of LEZ on different socioeconomic groups within Barcelona. By examining the relation between the variables of median household income and the proportion of non-compliant cars, the analysis reveals that lower-income groups do bear a disproportionate burden of distributional effects, as it is clearly seen that low-income populations tend to have a higher ownership of non-compliant vehicles, therefore showing that municipalities and neighbourhoods with lower incomes had a higher proportion of the population affected by the LEZ when it was implemented in 2020. This disparity is further evidenced by a significant reduction of non-compliant cars in poorer areas, showcasing a higher economic burden. This economic burden is compounded by the costs associated with updating or replacing these vehicles to comply with LEZ standards.

Furthermore, the analysis of public transport quality illustrates that lower transport quality does not directly correlate with income levels. Seeing that the income level of the municipalities and neighbourhoods does not appear to be a strong factor in public transport quality, it is theorised that the geographical aspects of each unit of analysis could have a stronger relationship with public transport quality. The spatial positioning of urban areas, especially those on the periphery, significantly impacts public transport services, often regardless of their economic status (Brovarone, 2021). This phenomenon, traditionally observed and studied within rural areas or on a larger peripheral scale, indicates a pronounced disparity in public transport quality (Binder & Mater, 2019; Baran & Agustiyn, 2021; Brovarone, 2021). However, this spatial effect on transport infrastructure is not exclusive to vast expanses but can also extend into more contained urban settings, such as the MAB (Lucas et al., 2018). While it's important to carefully consider the differences in scale and context when comparing the scarcity of public transport in vast peripheral areas to that in peripheral urban neighbourhoods or municipalities within a metropolitan area, the overarching pattern is clear: the further a location is from the centre, the worse its public transport tends to be. Therefore, this pattern underscores the importance of considering geographical peripherality alongside socioeconomic factors in urban planning and policy development. Peripheral municipalities, characterised by lower population densities and greater distances from urban centres, face inherent challenges in securing frequent and comprehensive public transport services (Lucas et al., 2018). This geographical disadvantage suggests a complex interplay between location and public transportation provision. Addressing the specific needs and challenges of peripheral municipalities and neighbourhoods is crucial for ensuring equitable access to high-quality public transport across all regions.

4.2 Population qualitative surveys Results

For the second empirical data collection step, a qualitative survey was carried out amongst the population of two neighbourhoods in Barcelona, Pedralbes and Ciutat Meridiana. Prior to delving into the survey findings, it is essential to articulate the reasoning behind selecting these particular neighbourhoods. This is followed by a detailed description and characterization of each neighbourhood, providing context that is instrumental for a comprehensive understanding of the survey outcomes. Then, the results of the surveys are presented.

4.2.1 Neighbourhoods' justification and contextualization

In the context of assessing the different experiences and adaptive strategies of the LEZ policy in Barcelona, the selection of Ciutat Meridiana and Pedralbes as focal neighbourhoods is both

methodologically sound and analytically insightful. The rationale for their selection is multi-faceted, as detailed below:

The inclusion of a comparative analysis between Ciutat Meridiana and Pedralbes via qualitative surveys was suggested and recommended by two mobility experts, Núria Pérez and David Andrés during an informal meeting that took place in the early stages of the thesis. The expertise of the mobility experts strengthens the research methods used in this thesis, affirming that contrasting these specific neighbourhoods could significantly enrich the understanding of LEZ policy's distributional effects for the following reasons:.

Firstly, the public transport quality of both neighbourhoods has been independently classified as 'poor' according to the evaluation criteria established within this thesis. This internal classification is further corroborated by the public transport accessibility index developed by the "Autoritat del Transport Metropolità" (ATM). Although the ATM's index was not directly employed in this thesis, its alignment with the findings substantiates the assertion that both Ciutat Meridiana and Pedralbes suffer from some of the worst public transport quality and accessibility within the city. This external validation amplifies the justification for examining these neighbourhoods for a nuanced exploration of LEZ policy adaptation.

Secondly, the socioeconomic dichotomy between Ciutat Meridiana, noted as the poorest neighbourhood, and Pedralbes, recognised as the second wealthiest in Barcelona, presents a unique opportunity. Such economic disparity offers an ideal environment for investigating how socioeconomic status plays a role in one's ability to adapt to and overcome the restrictions imposed by the LEZ policy. The assumption guiding this choice is that residents in these neighbourhoods may face more pronounced challenges in shifting their transport modalities due to inadequate public transport options, but due to economic disparities between the two neighbourhoods, Pedralbes might have an easier time adapting to the restrictions of the LEZ nonetheless.

Therefore, by comparing the spectrum of responses regarding the experiences of the populations in the selected neighbourhoods, critical insights were gained about the distributional effects of the LEZ policy in Barcelona.

Following, a detailed description and contextualization of the neighbourhoods are provided.

Pedralbes

The neighbourhood of Pedralbes is located in the district of Les Corts. It borders the Corts neighbourhood on Diagonal Avenue, the Sarrià neighbourhood to the east, and the Collserola mountain range to the north-west. The neighbourhood is named after the monastery of Pedralbes (founded in 1326) and the urbanisation of this area did not begin until the 20th century. It was born as a garden city project for the upper bourgeoisie, promoted by the Güell family. The garden city of Pedralbes was a relative failure, and finally, the Güell family gave King Alfonso XIII the Güell Tower, which became the Royal Palace of Pedralbes. Pedralbes is, today, the highest-level residential area in Barcelona, with large mansions surrounded by gardens or isolated blocks with luxury flats (Ajuntament de Barcelona, n.d. -a).

Figure 15. Map of the neighbourhoods of Barcelona, Pedralbes outlined. (Source: Ajuntament de Barcelona)

The demographic landscape of Pedralbes is defined by a population of 11.730 in 2022, spread over an area of 270.2 hectares. This results in a population density of 45 inhabitants per hectare. The community's diversity is marked by 17.9% of residents originating from foreign countries, predominantly from France, Italy, and Russia. The ageing rate stands at 152.2, reflecting the demographic trends affecting the area. The economic conditions of the neighbourhood are illustrated by a DHI per capita of 39.025€ and a DHI index of 1.76. Pedralbes had a registered unemployment rate of 2.6% in 2022, which is low compared to the 5.4% unemployment rate Barcelona had at the time (Ajuntament de Barcelona, n.d. -b).

The educational landscape of Pedralbes shows a highly educated population. Only a percentage of 0.2 of the population has insufficient instruction, while 16.8 % have only completed compulsory education. Further educational pursuits are reflected in 26.6% of the population completing non-compulsory high school and 54.1% attaining higher education qualifications, such as university degrees or CFGS (Higher Vocational Training) credentials. The area is also close to some of Barcelona's most prestigious educational institutions, adding to its reputation as an educated community (Ajuntament de Barcelona, 2023 -a.).

Regarding the transportation and mobility dynamics of Pedralbes, which are of particular relevance for this study, statistics show that there are approximately 500 cars per 1000 inhabitants. However, it is the public transport network of the neighbourhood that is lacking compared to the rest of the city, especially in the upper half of the neighbourhood. Within the borders of the neighbourhood, there is only one railway mode, the line L3 of the Barcelona Metro system, which is located in the very south. As a consequence, there are many parts of the neighbourhood that are up to 2 km away from the closest railway transportation mode. On the

other hand, the bus network is significantly more extensive, but once again, mostly only in the lower half of the neighbourhood. According to the Google Maps API, travelling from Pedralbes to the centre of the city (Plaça Catalunya), can take up to 20 minutes longer by public transport than with private transport, depending on the time. Moreover, the ATM public transport accessibility index shows how, especially the upper half of the neighbourhood, is rated with lower levels of public transport accessibility (Figure 16) (Autoritat Transport Metropolità, n.d.; Moovit, n.d -a., Google Maps, n.d).

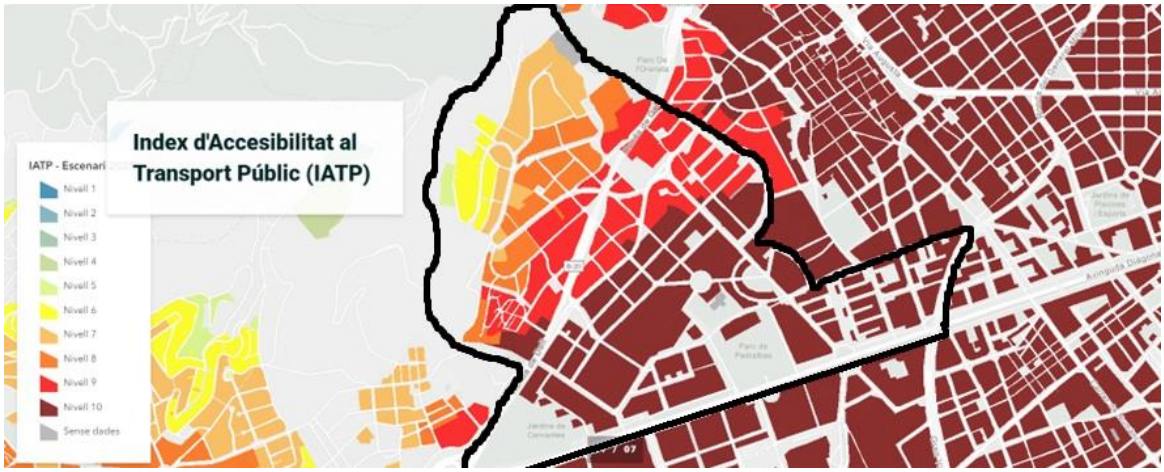

Figure 16. Public Transport Accessibility Index in Pedralbes. (Source: Autoritat Transport Metropolità, n.d.)

Regarding the political views of the neighbourhood of Pedralbes, a notable right-leaning political stance among residents is underscored by the 2023 Spanish general election results, where Partido Popular led with 43.52% of the votes, significantly above the 13.74% city-wide average. Furthermore, Vox, known for its far-right position, secured 11.47% of votes in Pedralbes, surpassing its overall Barcelona tally of 7.56%. These figures highlight the neighbourhood's distinct political orientation compared to the broader city landscape (Reig & Segura, 2023).

Ciutat Meridiana

Ciutat Meridiana is a neighbourhood located in the Nou Barris district of the city of Barcelona (Figure x). Ciutat Meridiana is located in a steep valley of the Turó de Roquetes and borders the neighbourhoods of Torre Baró and Vallbona and the municipalities of Montcada and Reixac.

Figure 17. Map of the neighbourhoods of Barcelona, Ciutat Meridiana outlined. (Source: Ajuntament de Barcelona)

The neighbourhood was built in 1963 by a promoter group that included Joan Antoni Samaranch in an area where a cemetery was supposed to be built, which was discarded due to the extreme humidity of the place. Its construction consisted of implanting a set of large housing blocks without the most basic equipment and without any kind of urban services, as was usual in Franco's urbanism. The first neighbourhood protests were due to the dampness of the flats. Then there was a demand for clinics, schools, and better street health (Ajuntament de Barcelona, n.d. -c).

Given its historical backdrop, Ciutat Meridiana's status as the city's most economically challenged neighbourhood is comprehensible. Despite progressive improvements over the years, the area remains emblematic of Barcelona's lower living standards.

The demographic landscape of Ciutat Meridiana is defined by a population of 10.808 in 2022, spread over an area of 35.50 hectares. This results in a population density of 291 inhabitants per hectare. The community's diversity is marked by 31.3% of residents originating from foreign countries, predominantly from Honduras, Pakistan, and Morocco. The ageing rate stands at 89.8, reflecting a much younger population than Pedralbes. The economic conditions of the neighbourhood are illustrated by a DHI per capita of 10.739€ and a DHI index of 0.48 in 2019. Pedralbes had a registered unemployment rate of 11% in 2022, which is very high compared to the 5.4% unemployment rate Barcelona had at the time (Ajuntament de Barcelona, n.d. -b).

The educational landscape of Ciutat Meridiana shows a significantly low level of education, especially compared to Pedralbes. In 2022, only a percentage of 2.6 of the population will have insufficient instruction, while an outstanding 68.8 % have only completed compulsory education. Only 18.9 % of the population have completed non-compulsory high school, and only

7.6% have attained higher education qualifications, such as university degrees or CFGS (Higher Vocational Training) credentials (Ajuntament de Barcelona, 2023 -b).

The one similarity Ciutat Meridiana shares with Pedralbes is the poor quality of public transport. Just like in Pedralbes, Ciutat Meridiana has a worse-than-average public transport network. Strictly within the borders of the neighbourhood, there is only one line of railway transportation, the L11 Metro line, which covers a very short distance only on the outskirts of the city. However, the adjacent neighbourhood, Torre Baró, counts with a train station that does travel to the city centre and is still very close to the eastern part of the neighbourhood, although with less frequency than the Barcelona Metro would. Regarding the bus network, Ciutat Meridiana has four buses. Given its compact size, Ciutat Meridiana's public transport quality slightly surpasses that of Pedralbes. The neighbourhood's smaller area ensures that residents are never too far from a mode of public transport, unlike some parts of Pedralbes. In figure 18 the ATM public transport accessibility index shows how the different central areas of Ciutat Meridiana are qualified in terms of public transport port accessibility (Autoritat Transport Metropolità, n.d., Moovit, n.d. -b, Google Maps, n.d.).

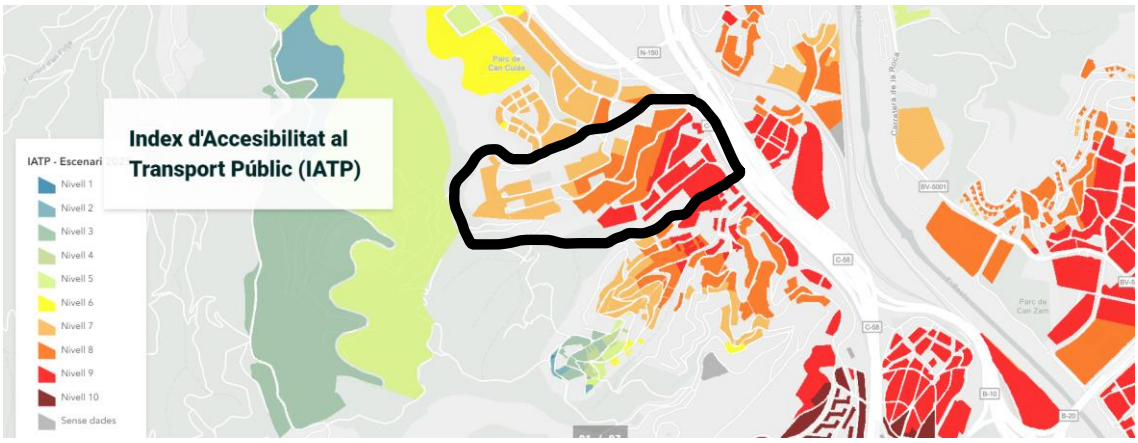

Figure 18. Public Transport Accessibility Index in Ciutat Meridiana. (Source: Autoritat Transport Metropolità, n.d.)

Regarding the neighbourhood's political views, Ciutat Meridiana is not as right-leaning as Pedralbes, but it is still more so than the average in Barcelona. Looking at the 2023 Spanish general elections results, it can be seen that the Partido Socialista de Catalunya, which is recognized as a central-left party led with 53.81% of the votes. However, Ciutat Meridiana was still one of the neighbourhoods with a higher percentage of votes towards Vox, which secured 10.48% of the votes in Pedralbes. (Reig & Segura, 2023).

4.2.2 Results qualitative surveys

This chapter delves into the nuanced experiences and adaptation strategies of residents in the previously described neighbourhoods, Ciutat Meridiana and Pedralbes, in response to the LEZ policy. Employing qualitative surveys as the data collection method, it was sought to capture the rich, subjective perspectives of individuals navigating the challenges and opportunities presented by this policy.

Ciutat Meridiana and Pedralbes, despite their contrasting socio-economic profiles, share the commonality of "poor" public transport quality, a factor that potentially complicates their adaptation to the LEZ policy. In synthesising the findings from the qualitative surveys, this

chapter endeavours to contribute to a more comprehensive understanding of the LEZ policy's societal implications. Examining the narratives emerging from Ciutat Meridiana and Pedralbes' citizens helps to better understand the multifaceted relationship between LEZ policy and socio-economic status.

Following, the results of the qualitative surveys are presented and analysed. First, a simple description of the answers to each question of the survey is presented, followed by a thematic analysis of the qualitative data the survey provides, which was carried out following the steps displayed in the methodology section.

Survey answers Description

The qualitative survey distributed amongst the residents of Pedralbes and Ciutat Meridiana counted 15 questions, 3 of which were about the demographics of the respondents. The full survey with all the questions and multiple-choice answers can be found in Appendix II. As mentioned in the methodology, five key themes were targeted to paint a comprehensive picture of the policy's multifaceted effects: **level of awareness and understanding**, **social and community effects**, e**conomic impacts, adaptation strategies,** and **overall satisfaction with the LEZ policy**. Through a blend of fifteen multiple-choice and open-ended questions, the survey gathers interesting data, offering a rich and nuanced understanding of the LEZ policy's impact in Pedralbes and Ciutat Meridiana. Unfortunately, the participation for this survey was quite low, with only 24 respondents, 14 from Pedralbes and 10 from Ciutat Meridiana. However, despite the low response rate, the results are informative as clear patterns in the responses of each neighbourhood are identified. The limitations and difficulties that contributed to the low participation will be unfolded in the Limitations chapter. In this sub-section, a description of the results is provided.

1. **Awareness:** Pedralbes residents showed complete awareness of the LEZ policy (100%), while Meridiana had a lower rate, with 70% aware and 30% unaware.
2. **Understanding:** Pedralbes had an even split in understanding the policy, with 50% finding it very clear and 50% somewhat clear. Meridiana showed less clarity, with only 20% finding it very clear, 30% somewhat clear, and a significant 50% not clear at all.
3. **Previous Reliance on Private Cars:** Half of the Pedralbes respondents relied on private cars, similar to 60% in Meridiana.
4. **LEZ Standards Compliance:** A discrepancy was noted in car compliance with LEZ standards—71.4% in Pedralbes versus 40% in Meridiana.
5. **Vehicle Changes:** Both neighbourhoods saw changes due to LEZ, with Pedralbes (28.6%) and Meridiana (20%) buying new cars. Meridiana also reported fines and the need to eventually change cars.
6. **Transportation Mode:** The LEZ policy did not significantly affect transportation choices in Pedralbes (92.9% no change) but did in Meridiana, where 60% changed their transportation mode, mostly towards public transport.

7. **Financial Impact:** The financial burden was felt differently; 71.4% in Pedralbes experienced financial impacts due to purchasing new cars, while in Meridiana, 70% reported no financial impact, citing fines and the need to sell non-compliant cars.
8. **Social Impact:** Pedralbes showed a mixed response, with 50% noting no social impact. In contrast, Meridiana displayed a significant social impact, with many unable to afford new cars and having to alter their work commute times.
9. **Awareness:** A large portion of Pedralbes (78.6%) and all of Meridiana were unaware of exemptions and authorization systems.
10. **Usage:** None of the participants from either neighbourhood had applied for or made use of exemptions.
11. **Satisfaction:** Pedralbes was divided in their satisfaction, while Meridiana expressed significant dissatisfaction (80% very dissatisfied).
12. **Gender:** Both in Pedralbes and Ciutat Meridiana, the majority of the participants, 80% or more, were male.
13. **Age:** In Pedralbes, 35,7% of the respondents were 18-25, 57.1% were between 26-60, and only 7,1% were over 60. In Ciutat Meridiana, only 10% of the respondents were between the age of 18-25, 50% of were 26-60 and 40% were over 60 years old
14. **Income levels:** In Pedralbes, 71,4% of the respondents reported having a high income, while 28,6% reported having a medium income. In Ciutat Meridiana, 80% of the respondents reported low income, and only 20% reported medium income.
15. **Suggestions and observations:** Sadly, none of the respondents from either Pedralbes or Ciutat Meridiana added any extra suggestions or opinions.

Thematic Analysis

Through the process of conducting the thematic analysis, coding was done according to the main five components of the survey. In Table 6, the codes associated with each survey theme are presented.

Table 6. Codes for each theme of the survey.

Theme	Codes
Policy Awareness and Understanding	"Aware of LEZ", "Understanding of LEZ details", "Confusion about policy", "Lack of information"
Adaptation Strategies	"Changing transportation mode", "Buying compliant vehicles", "Altering commute routes", "Experiencing fines"
Economic Impact	"Financial burden", "Purchasing new vehicles", "Penalties for non-compliance", "Inability to afford changes"
Social and Community Effects	"Impact on daily routines", "Changes in social interactions", "Community division", "Accessibility issues"
Overall Satisfaction	"Satisfied with LEZ", "Dissatisfied due to financial strain", "Neutral due to lack of effect", "Appreciation for environmental efforts"

Policy Awareness and Understanding

Pedralbes: Complete awareness of the LEZ policy was reported, with a split in understanding its specifics. This indicates that while the policy is known, its details and implications are not fully grasped by all. This is clearly reflected by looking at how many respondents declared not knowing about the exemptions one can apply for. This can mean two things; on the one hand, it shows how the higher-class population tends to very easily state that they understand a topic well, even if that might not be the case (Filippin & Paccagnella, 2012). On the other hand, it also shows that they do not have the need for these exemptions, which could be why they do not usually know about them. Both reasons could serve as an explanation.

Ciutat Meridiana: Lower awareness levels coupled with significant confusion about the policy's specifics underline a communication gap. In Ciutat Meridiana, all participants claimed to not know anything about the exemptions offered, even though most of them claimed to have a non-compliant car. This lack of understanding and knowledge of how the policy works is possibly due to a lack of resources or motivation to learn more about it, which is more common among lower socio-economic status populations. Knowing the low levels of higher-education in the neighbourhood, it can be assumed that residents of Ciutat Meridiana might be less involved in political matters and therefore less aware of how policies, specifically LEZ, work. This lower level of policy awareness and understanding, especially regarding the existing exemptions one can apply for, likely contributes to the difficulties residents face in adapting to the LEZ.

Adaptation strategies

Pedralbes: Adaptation to the LEZ in Pedralbes primarily involved purchasing new cars that meet LEZ standards, indicating a straightforward, albeit costly, approach to compliance. None of the respondents manifested the LEZ policy as the reason they now use public transport or travel at different times. The respondents who stated they commonly use public transport as their common mode of transportation made it clear that they already used it before the implementation of the LEZ.

> "Although I bought a new car that complied with the LEZ standards, I mostly use public transport" resident of Pedralbes

> "I've always used public transport" -Resident of Pedralbes

Ciutat Meridiana: Residents here showed more varied adaptation strategies, including changing transportation modes to public transport, facing fines, changing to more "uncomfortable" commuting times, and considering the future need to change vehicles. These strategies reflect constrained economic circumstances and a more complex negotiation with the policy's demands.

> "I go by car very early in the morning or late in the evening, when the LEZ is not in action." -Resident in Ciutat Meridiana

> "I have to go by train or bus to work now, and it sucks because it takes quite longer." -Resident in Ciutat Meridiana

Economic Impact

Pedralbes: Not many residents of Pedralbes experienced financial impacts, as a high proportion already owned a compliant car at the time the LEZ was implemented. However, the residents in this higher-income neighbourhood that did experience financial impacts did so primarily through the action of purchasing new, compliant vehicles. This suggests that some residents did experience a direct financial burden, but not a high proportion of them. This also implies a level of financial resilience that allowed for such adaptations, which is reflected in the following (translated) quote from one of the participants;

> "I bought a new car, but I was already planning on buying a new one even before realising it didn't comply with the LEZ emission standards. It also wasn't an expense to assume." -Resident from Pedralbes

Ciutat Meridiana: In contrast, this lower-income area saw a different type of economic impact. Although many respondents stated that they haven't bought a new car after the implementation of the LEZ, in many cases it was because they simply couldn't afford it. However, a couple respondents shared how they had faced multiple penalties for non-compliance. This highlights a stark economic strain where the policy inadvertently exacerbates existing financial inequalities.

These findings present a nuanced picture that challenges the initial analysis, which identified a correlation between the income levels of neighbourhoods and the percentage reduction of non-compliant vehicles. In the correlation analysis, it was observed that lower-income

neighbourhoods exhibited a greater reduction in non-compliant vehicles. However, a deeper examination reveals that, despite these reductions, lower-income areas still maintain the highest proportions of non-compliant cars. For instance, Ciutat Meridiana ranked fifth among neighbourhoods with the most non-compliant vehicles in 2021. This paradox suggests that while absolute numbers show a significant reduction of non-compliant cars in poorer neighbourhoods, the relative presence of non-compliant cars remains substantial in economically disadvantaged neighbourhoods. Furthermore, the observation that only a small fraction of respondents reported purchasing a new vehicle underscores the potential negative influence of the small sample size of the survey. Thus, it is acknowledged that this apparent discrepancy may also result from a coincidence inherent in a small sample, cautioning against overinterpreting these trends without further evidence.

> **"**I can't buy a new car, so I still use my old one**.** I have gotten a few fines for it, but there is nothing I can do because I still need to use the car."resident from Ciutat Meridiana

Social and Community Effects

Pedralbes: The impression of a social impact due to the implementation of the LEZ was mixed. Some residents experienced no change in the social dynamics of the neighbourhood and expressed their opinion on how they believed that most people weren't affected by the policy. The residents who stated that yes, they do think there have been social or community effects justify this by stating that some people have had to buy new cars. This may suggest that for most, the policy's implementation has been relatively seamless or inconsequential to their social lives, and the ones stating a social effect might be confusing the action of purchasing a new car with an actual change in the community dynamics.

> "We had to get a new car." -Resident from Pedralbes

> "Most people aren't affected because almost everyone I know already had a compliant car or could easily afford a new one." - Resident from Pedralbes

Ciutat Meridiana: Most respondents to Ciutat Meridiana think that the LEZ policy has had social and community effects in the neighbourhood. Significant social impacts were reported, including changes in work commute times, the struggle of having to share one compliant car between different family members when that wasn't necessary before, and a sense of being left behind due to an inability to afford compliant vehicles. This points to a deeper societal divide, where the policy not only affects economic standing but also social connectivity and community cohesion.

> "Before I had my own car I could use, but after this law was implemented, I have to ask my brother for his car and hope that he won't need it." resident from Ciutat Meridiana

> "People can't buy a new car because they don't have any money." resident from Ciutat Meridiana

Overall Satisfaction

Pedralbes: The divided satisfaction levels suggest that while some residents see the benefits or can easily adapt, others may have reservations about the policy's implementation or effectiveness. On one hand, it was quite noticeable that the respondents who shared a level of

somewhat satisfaction with the policy were quite young. They shared how they thought it was a good policy for the environment. On the other hand, more than once, respondents in Pedralbes expressed how their dissatisfaction came from the belief that they thought the policy was unfair to those who do not have enough money to buy a new car if they need it. Finally, some of the respondents who did not share any sort of impact from the policy still expressed a certain or high level of dissatisfaction towards the policy, which could be linked to political views.

Ciutat Meridiana: The most generalised reaction when the survey was being carried out in Ciutat Meridiana was how quickly most participants shared their negative thoughts on the policy, with little to no reservation in expressing their feelings towards the politicians that implemented it. A high level of dissatisfaction reflects broader concerns with the policy, including its fairness, the adequacy of support for adaptation, and its overall impact on residents' lives.

> "These Politicians don't care about us at all, this is just another way of controlling the population!" modified quote from a resident in Ciutat Meridiana

Interpretation and Insights

The thematic analysis of the LEZ policy demonstrates its differential impacts across socio-economic divides, particularly between the neighbourhoods of Pedralbes and Ciutat Meridiana. The findings further evidence and complete the distributional effects of LEZ revealed in the statistical correlation analysis. The results of the qualitative survey show that the policy, while aimed at mitigating environmental issues, might, in some cases, exacerbate social and economic disparities. Residents of Pedralbes, a higher-income area, exhibit greater awareness and adaptability to the LEZ requirements, such as affording newer, compliant vehicles. Conversely, Ciutat Meridiana, characterised by lower-income levels, faces challenges with awareness, understanding, and financial capacity to meet the LEZ standards, leading to significant dissatisfaction and hardship among its residents.

For this study, it was decided to include only two neighbourhoods in Barcelona, one of the richest and the poorest. However, it is important to reflect on what the findings could have looked like if all neighbourhoods had been included in the study. Pedralbes and Ciutat Meridiana represent the extremes in terms of socioeconomic status within Barcelona, as well as being some of the most socio-economically segregated areas of the city. Therefore, the focused sampling from these areas unveiled significant insights into the LEZ's impact. However, broadening the scope to include all neighbourhoods would have likely introduced a more complex and possibly less clear pattern of results. The strong differences in socioeconomic status across Barcelona's neighbourhoods could have diluted the clarity of findings, making it challenging to draw definitive conclusions about the LEZ's city-wide impacts. For instance, middle-income neighbourhoods, with varying degrees of vehicle compliance and public transport accessibility, might show mixed responses to LEZ policies, complicating the analysis of socioeconomic impacts. Moreover, a small sample size from a broader range of neighbourhoods might not have provided the statistical power necessary to discern significant patterns, potentially resulting in ambiguous interpretations of the LEZ's distributional effects. This broader approach, while offering a comprehensive view of the city's response to LEZ policies, would require more resources to accomplish a representative sampling size and have analytical capacity to manage the increased size and complexity of the results to ensure meaningful insights.

4.3 Interviews with experts' results

This chapter presents the findings from four expert interviews aimed at enhancing our understanding of LEZ, its socio-economic implications, and its distributional effects. While detailed descriptions of the interviewees are provided in the methodology chapter, a brief introduction to each expert is included here for context. The interviews with Nuria and David were more extensive, delving deeply into the thesis's results and methodology due to their prior familiarity with the specific topic of LEZ in Barcelona and their socioeconomic implications, as well as their previous knowledge of the thesis, which they gained during a meeting held in the early stages of the thesis's development. In contrast, discussions with Toon and Dick focused more broadly on sustainable mobility transitions, though both conversations also significantly touched upon the thesis results.

The analysis is structured into four subsections, each dedicated to one interview. The format for each section is consistent: starting with the interviewee's general knowledge on LEZ and their views on its distributional effects, followed by their perspective on the thesis's relevance and research quality. Specifically, the discussion will assess their opinions on the soundness of the quantitative research methodology and their insights on its findings, along with their thoughts on the survey results. Finally, each subsection will conclude with the interviewees' personal viewpoints on the efficacy of LEZ policies and suggestions for improvement, offering a comprehensive overview of expert opinions on the matter.

4.3.1 Interview with Núria Pérez

Núria Pérez Sans is a licenced geographer who works as the head of the mobility area at Institut Metròpoli. She has made significant strides in understanding mobility behaviours and needs through applied research. Her work encompasses planning and managing urban mobility, analysing transport databases, and contributing to the Metropolitan Urban Mobility Plan of the MAB, including co-authoring a pivotal 2022 report on the socio-economic impacts of the Zona de Baixes Emissions Rondes de Barcelona.

The interview with Núria provided several valuable insights directly relevant to the research on the distributional effects of LEZ in Barcelona. Núria's expertise in mobility and inequality and her previous experience in similar research enrich the analysis with perspectives on how LEZ policies intersect with social justice, economic disparities, and urban mobility patterns.

The interview highlights the complexity of addressing social inequalities within urban mobility policies and suggests that while LEZ policies aim to improve environmental conditions, their socio-economic impacts are nuanced and multifaceted. Núria's observations on the distributional effects of LEZ policies, particularly their impact on lower-income groups and small businesses, along with the challenges of achieving equitable mobility, underscore the need for comprehensive policy approaches that consider the diverse needs of urban populations. Therefore, it can be argued that Núria agrees on the relevance of the research, as multiple times throughout the interview she highlights her interest in and importance of the topic.

However, she also argued the importance of being aware of the fact that socio-economic injustices are embedded in many aspects of the system and that mobility is not the main vector of inequality but rather energy, housing, and food. Nonetheless, she acknowledges how it does play a big part.

Regarding the first step of the analytical framework, Núria found the results of the correlation analysis coherent with her own observations and research. She validated the approach and conclusions drawn from the analysis, indicating that the findings align well with existing knowledge and data patterns observed in similar studies. This acknowledgement from Núria supports the reliability and relevance of the correlation analysis conducted in this thesis.

When discussing the methodology of the statistical correlation analysis, Núria took the opportunity to specifically talk about the methodology used to determine public transport quality. She mentioned how she appreciates the approach but also acknowledges its complexity. She confirmed that comparing accessibility and the differential in travel time between private and public transport as a measure of public transport quality is a delicate yet valid approach. She mentioned how this method aligns with studies she has conducted before, comparing the travel times between private and public modes of transport to evaluate quality. Núria supports the methodology's reasoning, recognising the importance of time over mere accessibility when assessing public transport quality. She agreed that the significant factor is the time differential rather than accessibility alone, and that the viability of a modal shift depends highly on how much more time people need to invest in commuting. Moreover, she highlighted how it would be valuable, but knowledgably quite complicated, to gain better insight on how much time people are willing to invest in travelling by public transport versus private means. She argued that if a widespread survey could be distributed amongst the population, an average could be calculated, and efforts could be made to make public transport time more competitive,.

Nonetheless, she believes that it is true that both high-income and low-income areas can exhibit varied levels of public transport accessibility, and there isn't a straightforward pattern correlating economic status with public transport quality. She also agrees that in certain cases, the geographic characteristics of a neighbourhood or municipality might play a bigger role in this regard.

For the second part of the analytical step, the qualitative surveys, Núria enthusiastically appreciated the selection of Ciutat Meridiana and Pedralbes, recognising it as a strategic choice that reflects the socio-economic diversity and disparities within Barcelona. She acknowledged that these neighbourhoods represent two distinct socio-economic extremes, making them ideal subjects for studying the impacts of LEZ policies. This option enables a thorough examination of the ways in which these policies impact various community sectors, ranging from inhabitants of more economically disadvantaged neighbourhoods to those living in affluent districts.

Her approval stemmed from the understanding that comparing these neighbourhoods can uncover nuanced insights into the distributional effects of LEZ policies, highlighting disparities in mobility access, economic burdens, and social implications. Núria's perspective validates the methodological approach, suggesting that the contrasting socio-economic statuses of Ciutat Meridiana and Pedralbes offer valuable data for assessing the equity and effectiveness of environmental policies within urban settings.

Núria views the results of the qualitative survey positively, acknowledging them as coherent and sensible. Núria's feedback highlighted the importance of qualitative insights in understanding community perceptions and the nuanced impacts of policy implementations. Despite the sample size being relatively small, she believes the findings provide meaningful contributions to the

discourse on urban mobility and social equity, reinforcing the survey's value in capturing street-level perceptions. Nonetheless, Núria suggested that the political leanings within neighbourhoods like Ciutat Meridiana and Pedralbes, with a higher percentage of votes for far-right parties such as Vox and PP, might influence residents' perceptions and opinions on the LEZ policy. She explained how it is important to take into consideration political ideology because it can impact public reception and support for environmental initiatives, suggesting that understanding the local political context is crucial for the effective implementation and acceptance of such policies.

Finally, Núria suggested several policy adjustments aimed at making LEZs more equitable, such as targeted financial aid, improved public transportation options, and comprehensive communication strategies. These recommendations serve as valuable add-ons to the thesis, offering concrete steps for policy improvement.

Specifically, when asked for her personal opinion on whether the LEZ is an effective policy to reduce air pollution while also being equitable, Núria discussed the idea of implementing an urban toll as a potentially “better” policy measure. She expressed a preference for a policy where any use of private vehicles is subject to a toll, advocating for a "soft toll" that would not be overly expensive but would apply to everyone equally, with potential discounts for clean vehicles or depending on the number of occupants, although she acknowledges the difficulty in verifying such criteria.

Núria suggested this approach as a way to reduce the use of private vehicles in a more general way and promote more sustainable urban mobility. She argued that such a toll should not be seen merely as a transport policy but as part of a broader strategy that includes raising funds for public transportation and other policies. This idea of an urban toll complements discussions on LEZ policies by offering a more inclusive approach that could penalise private vehicle use more broadly rather than focusing solely on the type of vehicle or its emissions level. It reflects a holistic view of urban mobility challenges and solutions.

Based on Núria's insights throughout the interview, it appears she acknowledges the LEZ policy's potential for mitigating air pollution but also expresses concerns about its socio-economic impacts. She likely emphasised the importance of implementing complementary measures to address potential disparities caused by the policy. Thus, while recognising its environmental benefits, Núria might advocate for a more holistic approach that includes the LEZ policy as part of a broader strategy to ensure equitable outcomes alongside environmental improvements.

4.3.2 Interview with David Andrés

David Andrés Agromedo is a mobility technician at Institut Metròpoli who specialises in mobility planning with a focus on externalities such as air pollution, noise, and social cohesion. He has contributed to the Metropolitan Urban Mobility Plan of the MAB and has co-authored studies that delve into the social dimensions of mobility, including the notable 2022 report on the socio-economic impacts of the Zona de Baixes Emissions Rondes de Barcelona.

In the interview with David Andrés, his insights significantly contribute to the understanding of the distributional effects of the LEZ policy in Barcelona, complementing the thesis's themes and objectives. Working alongside Núria Pérez at Institut Metròpoli, David's expertise offers a profound evaluation of the mixed-method research strategy employed in the thesis,

underscoring the importance of a holistic approach that blends quantitative data analysis with qualitative insights from surveys and expert interviews. David's opinions, as extracted from the interview transcript, provide critical insights into the thesis's methodologies, outcomes, and overall research direction.

In the beginning of the interview, David delved into the LEZ policy, highlighting how it primarily impacts older, more polluting vehicles, which often belong to individuals with fewer resources, making them most susceptible to the policy's effects. However, he acknowledged the dual nature of mobility, suggesting that when considering mobility beyond private vehicle use, the outcomes might differ. David noted that LEZs are mostly implemented in urban areas with a high population density to enhance air quality and urban living conditions. He underscored the importance of considering the broad spectrum of urban mobility options, such as walking, public transit, and cycling, to assess the policy's equity implications fully. He also questioned the straightforward link between LEZs and social inequity by emphasising Barcelona's robust public transport network and varied mobility habits that lessen dependence on private vehicles. Following this reasoning, David argued that while it shouldn't be stated that LEZs specifically promote equality or inequality, he emphasised the need for a detailed analysis of social equity concerns related to LEZs within particular cases in order to have a better understanding of if and how distributional effects stemming from LEZ policy manifest.

The interview then moved on to assessing the methodology and results of the data collection steps, focusing first on the correlation statistical analysis followed by the qualitative surveys. Throughout the interview, David validated the research by acknowledging the comprehensive and nuanced approach taken in the analysis of the LEZ policy's effects. He appreciated the mixed-method research strategy, combining quantitative data analysis with qualitative insights, which he views as crucial for understanding the multifaceted impacts of LEZ policies on different demographic and socioeconomic groups in Barcelona. He also praised the robustness of the statistical correlation analysis and the qualitative surveys conducted in the neighbourhoods of Pedralbes and Ciutat Meridiana, highlighting the value of capturing both numerical trends and the personal experiences of residents affected by LEZ policies.

David's general opinion on the statistical correlation analysis presented in Mariona's study is cautiously critical. He acknowledged the relevance of the study and recognised the moderate negative correlation identified, suggesting a relationship between economic prosperity and adherence to environmental regulations. However, David remarked that the correlation, while within acceptable parameters, appears somewhat marginal. His feedback implied a recognition of the study's attempt to quantify relationships but also hints at the complexity and challenges of capturing the full scope of LEZ policy effects through statistical means alone. This perspective suggests that while he finds the analysis to be valid and agrees that the outcomes make sense, it might not fully encapsulate the nuanced impacts of the policy, pointing towards the need for broader and perhaps more detailed investigations to understand the LEZ's true effects.

Regarding the correlation between non-compliant car percentage and income, David gave very interesting insight on the distinction between vehicle fleet and vehicles in circulation to highlight an often-overlooked aspect of mobility and emissions analysis. He used a practical example to illustrate his point: comparing a newer, less-polluting BMW that he uses daily to an older, more polluting 600 model used every 15 days. Despite the stark difference in their usage and

emissions, both vehicles are counted equally in statistical analyses, which could skew the interpretation regarding the number of “people affected” by the LEZ policy. However, he does not think that the research at hand should have been done differently, as there is not enough detailed information on vehicles in circulation vs. vehicle fleet. Moreover, he validated the research results by agreeing that regardless of the difference between vehicle fleet and vehicle circulation, it is true that a more economically challenged population tends to own older and therefore more polluting vehicles.

Regarding the correlations between public transport quality and income, David's opinion on the methodology used for qualifying the quality of public transport in this thesis reveals an insightful critique and suggestion for potential improvement. The original methodology aimed to provide a basic evaluation of public transport quality by estimating the travel time difference between car and public transport to a central location in Barcelona was critiqued by David for its simplicity and potential inaccuracy in reflecting the true quality of public transport. Although he acknowledged that this approach is not wrong, he suggested a more robust method that could have been utilized to assess public transport quality. Specifically, David pointed out that the Authority of Metropolitan Transport (ATM) has published an accessibility index covering the entire MAB that provides a standardized measure of public transport accessibility, considering various factors such as proximity to bus, metro, and tram stations, which he believes would have served the analysis better than the method of comparing travel times to a central point in Barcelona using Google Maps. However, he agreed that the results might not be too different, although it is just a hypothesis that should be tested by actually doing the correlation analysis using the ATM index. Nonetheless, David still agrees with the research’s conclusion that public transport quality and income are not related in the case of the MAB or Barcelona.[1]

Regarding the qualitative surveys, David, echoing Núria's sentiments, highlighted the strategic selection of Pedralbes and Ciutat Meridiana due to their starkly contrasting socio-economic profiles, underscoring the insightful comparison this choice provided.

When talking about the survey’s results, the most insightful discussion was about the discrepancy between subjective experiences and objective realities concerning the LEZ policy's impact. David suggested that personal experiences or declarations about how individuals perceive the policy's effects on their lives may differ significantly from the objective data on its actual impact. David noted that not many people, particularly from lower-income areas like Ciutat Meridiana, would initially claim the policy is beneficial, indicating a generally negative subjective perception.

He also raised concerns about how political affiliations and beliefs might influence people's evaluations of the policy. David pointed out that the LEZ policy is often associated with specific political groups, which may not have been the most supported in certain areas, such as Pedralbes or Ciutat Meridiana. He observed that the polarisation of politics in recent years could lead to initial impressions of policies being shaped by certain ideologies. This polarisation suggests that subjective opinions on the LEZ could be heavily influenced by political stances rather than an objective assessment of its impacts.

[1] The reasoning to why David’s suggestion was not followed is developed in section 4.3.5

He therefore emphasised the importance of asking about objective facts, such as daily commutes and transportation methods, to evaluate the policy's impact more accurately. He implied that a discrepancy often exists between subjective perceptions of being affected by the policy and the objective reality of its impact, as evidenced by previous studies he mentions. These studies found a significant difference between subjective opinions on how much individuals felt affected by certain policies and the actual effect analysed through population mobility data.

As a general conclusion on David's opinions on the research outcomes, it can be interpreted for the interview that he validates the research's results and its interpretations on the fact that while LEZs aim to reduce air pollution and promote environmental sustainability, they may inadvertently exacerbate socioeconomic disparities by imposing disproportionate burdens on lower-income populations. This, according to David, is a crucial aspect of the research that contributes significantly to the discourse on sustainable urban policy and social justice. Nonetheless, it is also clear that he believes that some things could have been done differently to gain more valuable insights, as well as to offer reflections that help understand and relativize the results.

David further enriched the research by elaborating on his perspective regarding the LEZ policy's environmental effectiveness and its socio-economic implications. He critiqued the LEZ for not being impactful enough in reducing pollution or affecting mobility significantly. David suggested that to make the LEZ more effective, the policy should impose stricter limits on more vehicles, including those with yellow or B labels (which refer to a stricter category of emissions labels in the context of European emission standards). However, he acknowledged that making the policy stricter increases even more the importance of conducting socio-economic studies of the affected population to understand which groups are most impacted and why. He proposed an approach that aims to discern the necessities and types of mobility that could be considered essential versus non-essential, suggesting that some types of vehicle use could be more critically restricted or redirected towards sustainable alternatives.

4.3.3 Interview with Toon Meelen

Toon, an assistant professor in Innovation Studies at Utrecht University, focuses on innovations in transport, energy, and housing, building on insights from Sustainability Transitions, Innovation Studies, and Political Economy. His research spans interdisciplinary approaches, analysing how transport innovations, among other areas, can contribute to sustainability transitions. He emphasises in his work the importance of integrating social justice into sustainability initiatives to ensure equitable outcomes for all societal groups. However, Toon's direct engagement with LEZ began during his time working in the UK, where he was involved in a project concerning fleets of commercial vehicles in response to the implementation of LEZs, notably in London and Oxford.

Toon's project focused on evaluating how small to larger companies could transition their fleets to electric vehicles, considering the challenges posed by LEZ policies. This work encompassed a broad range of organisations, including local furniture delivery companies, school bus operators, and council services. The diversity of these organisations allowed for a comprehensive analysis of how different types of fleets could adapt to LEZ requirements.

Toon explained how the study found that larger companies generally had fewer difficulties complying with LEZ standards due to their more organised policies on fleet management and the ability to renew their fleets with newer, compliant vehicles. In contrast, smaller companies and self-employed individuals faced greater challenges. These entities often had less structured fleet management and were financially constrained, making it difficult to replace older, non-compliant vehicles. As a result, smaller businesses experienced more significant impacts from LEZ policies, including concerns over unfair competition and the justice and inclusiveness of these environmental measures.

This comprehensive overview of Toon's research on LEZs and their impact on commercial fleets in London sheds light on the multifaceted challenges associated with implementing LEZ policies in urban settings. By examining the effects not just on individual drivers but also on various types of businesses, Toon's work highlights the critical need for LEZ to be both equitable and sensitive to the wide range of economic and operational circumstances faced by stakeholders that go beyond private drivers. It emphasises that the success of LEZ initiatives hinges on their ability to balance environmental objectives with the practicalities of those who are most directly impacted, including small businesses and self-employed individuals.

Regarding Toon's opinion on the research strategies and methodology, although during the interview he did not go into too much depth on his thoughts about the methodology, Toon's early statement suggested a preference for comprehensive, multi-faceted approaches to studying mobility and LEZ effects. His own work incorporates various research methods, including case studies and systemic analyses, aligning with the thesis's combination of quantitative and qualitative analyses. He did share praise for the fact that three different data collection steps were utilised, mentioning how including both quantitative and qualitative data collection strategies added significant value to the thesis. This implies a validation of the thesis's methodological choices, suggesting that complex policy impacts require diverse research tools to fully understand.

Regarding the results of the statistical correlation analysis, Toon shared his agreement with the results and acknowledged that they seemed to make sense. Although the conversation regarding the statistical analysis did not go into too much depth, he did share that it would have been interesting to include population density as a control variable in the analysis of the correlation between transport quality and income. He suggested employing regression models that account for both population density and transport quality. He explained how this approach would enable a more precise understanding of their interrelation by isolating the effects of socio-economic status from those of population density. By doing so, the analysis could more accurately reflect the nuanced impacts of urban spatial distribution on transport quality, ensuring a comprehensive evaluation of how socio-economic variables influence transport experiences in different population density contexts. Toon's recommendation reflects the general importance of understanding and taking into consideration the complex dynamics of urban transport systems.

Moving on to the qualitative interview's results, just like Núria and David, Toon delved as well into the importance of taking political views and subjective opinions into consideration, emphasising the importance of separating genuine criticisms from political controversy. Toon noted that the political backlash against LEZ policies is often disproportionate to the actual

disadvantages they present. He suggests that the intensity of the backlash is more political than rooted in the direct impacts of the policies themselves. He mentioned that, especially post-pandemic, right-wing activists and various political parties have leveraged LEZ issues to connect them to broader concerns about limiting freedoms and promoting conspiracy theories. This indicates a strategic use of LEZ policies by political groups to advance broader agendas rather than focusing on the policies' environmental or social impacts. Moreover, he also pointed out that the phenomenon of political backlash to traffic reduction measures, including LEZ, is not unique to any one country but is observed internationally. He mentioned how in places like the UK and the Netherlands, even modest traffic reduction measures can trigger significant political reactions, affecting both local and national politics.

Towards the end of the interview, Toon delved into the intricacies of the LEZ labels in Barcelona, focusing on their reliance on Euro standards to determine vehicle compliance. He articulated a critical perspective on how these standards, while necessary, might not fully encapsulate the broader environmental and social impacts of vehicle use in urban settings. He acknowledged that while the current LEZ labels, which are primarily based on Euro emission standards, serve as a straightforward method for categorising vehicles according to their environmental factors, he points out that this system may be overlooking other significant factors that could also play an important role in effectively reducing emissions and potentially help make the policy more equitable. Toon suggested that incorporating vehicle weight and dimensions into the LEZ labelling criteria could offer a more comprehensive approach to addressing urban environmental challenges. He argues that larger and heavier vehicles, which are more likely to be owned by wealthier individuals, not only contribute to emissions but also exacerbate other urban issues such as congestion and the monopolisation of public space. By broadening the criteria for LEZ compliance to include vehicle size and weight, Toon believes that the policy could better reflect the diverse impacts of different types of vehicles on urban environments. This adjustment could lead to a more equitable distribution of environmental responsibilities among citizens, ensuring that those who contribute more significantly to urban environmental. Nonetheless, he also made it clear that such a nuanced approach would not come without challenges, particularly the need for clear, accessible criteria that vehicle owners can easily understand and comply with. He also notes the importance of considering the impact on electric vehicles, which tend to be heavier than their combustion-engine counterparts. Despite these challenges, he advocates for a more differentiated system that could incentivize the use of smaller, less impactful vehicles, especially in densely populated urban areas. With this suggestion, it is clear that he agrees on the importance of refining LEZ policies to ensure they better align with the broader goals of sustainable urban mobility and social justice.

In general, Toon's opinions and experiences lend credence to the thesis's exploration of LEZ impacts. His emphasis on the need for inclusive, equitable transitions in mobility systems supports the thesis's investigation into the distributional effects of LEZ policies. By highlighting real-world challenges and potential solutions, Toon implicitly validates the thesis's results, reinforcing the importance of these considerations in policy evaluation.

4.3.4 Interview with Dick Ettema

Prof. Dr. . Ir. Dick Ettema works as Professor of Urban Accessibility and Social Inclusion at Utrecht University. He delves into how demographic, economic, societal, and technological changes influence accessibility and daily life within cities and urban regions.

To start the interview, Dick dug into his extensive experience in mobility studies. His research spans the implications of these factors on travel behaviour, which are usually affected by a person's socioeconomic status, where they live, etc. He has also explored how policies might influence these behaviours. He has further investigated well-being effects related to travel and the implications of transport policies on transport poverty and social participation. Finally, he mentioned how the study he is most involved in at the moment is about inclusive transition towards electric mobility and highlighted his concerns about how such transitions might disproportionately affect lower-income groups, who may face barriers to accessing newer, cleaner transportation options. Dick stresses the importance of ensuring that mobility policies do not inadvertently widen social inequalities but rather support inclusive access to sustainable transportation for all community members, which resonates very well with the thesis.

When asked about his understanding of LEZ policies, he explained that he understands LEZ policies primarily from a local air quality improvement perspective but questions their broader sustainability impact and their effectiveness in addressing pollution in areas beyond city centres.

Dick's views on research strategies and data gathering methods weren't explicitly detailed during the interview but are implicit in his comprehensive approach to studying mobility, emphasising the importance of econometric modelling and survey studies. Nonetheless, when looking at the results of the statistical correlation analysis, he suggested that they are significant and seem to make sense. He noted, however, that the impact of the LEZ within the MAB municipalities, which fall outside the boundaries of the LEZ, could vary based on the population's necessity of accessing the city, and suggests that for further research, it would be interesting to somehow gather data on these needs. Regarding public transport quality, he also made the observation that richer neighbourhoods are often found in the periphery of the city, where there is more space for bigger houses but might therefore have the worst public transport quality. However, he implied that because a wealthier population tends to rely more on private transport, they aren't as affected or bothered by the lack of public transport quality. This observation underscores the rationale for selecting Pedralbes and Ciutat Meridiana as the focal points of the qualitative survey. The choice was driven by the desire to investigate how contrasting socioeconomic backgrounds influence residents' experiences, perceptions, and responses to LEZ policies, particularly in the context of worse public transport quality, which both neighbourhoods have, despite Pedralbes being a much wealthier neighbourhood than Ciutat Meridiana.

Moving on to the qualitative surveys, a particularly interesting discussion between distributional justice and procedural justice arose. When discussing the fact that most residents are not aware of the available exemptions of the LEZ Dick emphasized that to avoid this problem, the focus has to switch to procedural justice rather than distributional justice. He highlighted the importance of informing the public well about LEZ policies, which differs from the need for policies to equitably distribute environmental, social, and economic impacts so they don't disproportionately disadvantage certain communities.

Finally, regarding Dick's general view on sustainable mobility transitions, the conversation focused especially on the topic of electric cars, as that is Dick's main area of expertise. Regarding the justice implications of transitioning towards electric cars, Dick expressed concern about the equity of such a move, particularly highlighting the high cost of electric vehicles and the lack of a developed second-hand market. He noted that the transition primarily benefits those who can afford the initial high costs of electric vehicles, including subsidies aimed at early adopters, typically higher-income individuals. This raises obvious justice issues, as low-income people may find it challenging to participate in the transition, potentially exacerbating existing inequalities.

Dick also discussed the broader implications for a sustainable transport model, questioning whether the push towards electric private vehicles is the most effective approach. He acknowledged that while transitioning to electric vehicles is necessary in a society heavily reliant on cars, it is not sufficient on its own to achieve sustainability in transportation. Dick advocates for a multifaceted approach that also focuses on reducing car reliance through urban planning that promotes transit-oriented development, better active transport infrastructure, and shared mobility options. He suggested that such comprehensive strategies are essential for a more equitable and sustainable mobility transition, emphasising that simply replacing fossil fuel vehicles with electric ones does not address the need for overall reductions in mobility demand and the environmental impacts of transportation.

4.3.5 Interviews insights & intermediary conclusion

The collective insights from interviews with Núria, David, Toon, and Dick converge on several critical themes relevant to the discourse on LEZ and sustainable mobility. These experts, each with a unique professional background and perspective, underscore the complexity of implementing LEZ policies in a manner that is both effective for environmental sustainability and equitable for all urban inhabitants. The insights from these interviews answer sub-question 4, enhancing and contextualising the findings of the thesis.

All interviewees highlight the significance of distributional justice in the context of LEZ implementation. The experts collectively argue that LEZ policies must be scrutinised for their distributional effects, particularly on lower-income populations, who may be disproportionately affected due to their reliance on older, non-compliant vehicles. This concern points to the necessity of policies that not only promote cleaner air but also ensure that the transition towards more sustainable modes of transportation does not exacerbate existing social inequalities.

Moreover, **procedural justice** emerges as a pivotal theme, emphasising the importance of inclusive policy-making processes. The interviews suggest that successful LEZ implementation requires engaging with affected communities to ensure their perspectives and needs are considered in the policy design. This approach not only enhances the legitimacy of LEZ policies but also facilitates more effective and accepted solutions. However, there is also a strong consensus amongst the experts on the importance of taking political landscapes into consideration when considering the population's opinions on LEZ policies. They collectively emphasise that political affiliations and ideological positions can significantly impact public reception and support for LEZ initiatives. Addressing political concerns and ensuring procedural justice is crucial to mitigating backlash and fostering broad acceptance of sustainable mobility policies. Moreover, the citizen's subjective perception of LEZ negative impacts is also commonly

pointed out by the experts, highlighting the importance of making sure that objective questions are asked in order to get a real view of the impacts of the policy.

The discussions with the experts also reveal a consensus on the need for a **holistic approach** to sustainable mobility. The experts all advocate for integrated strategies that combine LEZ policies with improvements in public transportation, infrastructure for active mobility, and urban planning that reduces the necessity for car usage.

Finally, regarding the validation of the thesis's **methodology and the research findings**, the experts' insights collectively endorse the mixed-method research strategy adopted in the thesis, combining quantitative data analysis with qualitative insights from surveys and expert interviews. This methodological approach is praised for its ability to capture the multifaceted impacts of LEZ policies on different demographic and socioeconomic groups. Specifically, Núria and David appreciate the comprehensive and nuanced analysis, highlighting the strategic selection of neighbourhoods for qualitative surveys that reflect socio-economic diversity, thereby enriching the research's depth. Moreover, the experts generally align with the thesis's findings. Núria's validation of the correlation analysis and the approach to determining public transport quality, alongside David's cautious critique yet recognition of the correlation analysis's relevance, underscore the soundness of the research outcomes. They acknowledge the complexity of the socio-economic injustices embedded within urban mobility policies, validating the thesis's examination of distributional effects and the nuanced implications of LEZ policies. It is important to point out that the reason for not following David's suggestion to use the ATM transport accessibility index was that, while the index is indeed insightful and lends further support to the thesis arguments, the chosen methodology to assess public transport quality aimed specifically at evaluating the potential shift in transport models through the lens of time, taking inspiration from Verbeek & Hincks (2022).

In sum, the interviews with Núria, David, Toon, and Dick complement each other by painting a comprehensive picture of the challenges and opportunities associated with LEZ policies and sustainable mobility transitions. Their collective insights stress the importance of equitable, inclusive, and integrated approaches to policy-making. These conclusions not only validate the thesis's exploration of LEZ's distributional effects but also offer a blueprint for future research and policy development aimed at achieving sustainable and just urban mobility.

5 Discussion

In the following section, the implications of the main findings of this thesis are explored, followed by the contextualization of the findings within the existing scientific literature. Then, the validity and limitations of the research are discussed. Concluding the chapter, policy suggestions and future research directions are presented.

5.1 Discussion of the findings

The extensive findings from both the statistical correlation analysis and qualitative surveys carried out in this thesis reveal that the LEZ policy in Barcelona does have some distributional effects that are disproportionally felt by lower-income households. These findings are further confirmed by the four interviews with mobility experts.

The statistical correlation analysis revealed nuanced insights into the socio-economic disparities influenced by LEZ policies. The analysis of median household income, the proportion of non-compliant cars, the quality of public transport, and households with newer cars across municipalities and neighbourhoods of Barcelona provided a general view of the economic and mobility impacts of LEZ. The results highlighted how lower-income groups are disproportionately affected by the policy because of their higher ownership of non-compliant cars and therefore by the economic burden of updating or replacing non-compliant vehicles. The policy has a varied impact on mobility and accessibility as well. The analysis of transport quality revealed how different neighbourhoods and municipalities have to face significantly higher travel times when using public transport. However, the correlation analysis revealed that lower transport quality is not necessarily related to income levels, showcasing that both rich and poor neighbourhoods sometimes face poorer public transport quality regardless of their socio-economic status.
Nonetheless, the findings indicate that in scenarios where lower-income neighbourhoods or municipalities encounter subpar transportation quality, they are significantly more challenged in adapting to the LEZ restrictions, suggesting a heightened vulnerability to policy impacts due to limited mobility options.

Relying solely on statistical correlation analysis to conclude the distributional effects of LEZ policies may not fully capture the nuanced impacts on different socioeconomic groups. Although the correlations between income levels and the ownership of non-compliant vehicles—as well as the reduction of such vehicles in lower-income neighbourhood's—indicate that these populations are more adversely affected by LEZ policies, the moderate strength of these correlations suggests that the distributional effects might not be as pronounced as initially thought. This ambiguity underscores the importance of incorporating qualitative research methods, such as surveys, to gain a deeper understanding of how lower-income communities experience the LEZ policy. Through qualitative inquiries, detailed personal experiences can be accessed, uncovering the complex ways in which economic burdens are felt and managed, thereby enriching the comprehension of the policy's distributional effects beyond what quantitative data can reveal.

The qualitative surveys conducted in the neighbourhoods of Pedralbes and Ciutat Meridiana offered in-depth perspectives on the lived experiences of residents affected by LEZ policies. These surveys illuminated the diverse ways in which policies impact daily life, from changes in transportation habits to financial strains and social exclusion. Notably, the surveys revealed a critical disparity in the impacts and acceptance of the LEZ policy, with lower-income residents facing greater challenges adapting to these regulations. This highlights the necessity of

considering the socio-economic context more intensely in the formulation and implementation of the policy to avoid unintended consequences that may widen existing social gaps.

The discussions with experts further validated the findings, providing professional insights into mobility patterns, behavioural shifts, and potential policy adjustments to mitigate adverse distributional effects. Conducting semi-structured interviews with four experts from diverse backgrounds revealed different perspectives regarding the primary concerns of LEZ policies and their resolution strategies. However, a consensus emerged among these experts, highlighting a unanimous acknowledgment of the pronounced socio-economic impacts of such policies. This consensus underscores the need for a stronger consideration of the socio-economic effects, particularly on lower-income populations who disproportionately bear the burden of LEZ restrictions. Moreover, these conversations underscored the importance of integrating expert knowledge into evaluating and refining urban environmental policies to ensure they are equitable and effective.

This thesis contributes significantly to the scientific understanding of the intersection between environmental policies and social justice. By providing empirical evidence of the distributional effects of LEZ policies in Barcelona, it fills a critical gap in existing literature, offering a nuanced analysis of how such policies impact different socio-economic groups. It challenges the idea that environmental policies are inherently equitable and calls for a more nuanced approach to policy design that considers the socio-economic realities of affected communities, ensuring that socio-economic dimensions are not only recognised but are also central to the development and implementation of the LEZ policy in Barcelona.

Moreover, this research highlights the importance of engaging with and incorporating the perspectives of vulnerable populations in the policymaking process. It advocates for the adoption of intersectional policy frameworks that address inequalities holistically, ensuring that efforts to improve urban air quality do not inadvertently reinforce social and economic disparities.

In conclusion, the findings of this thesis underscore the need for policies that are both environmentally effective and socially just. It emphasises the importance of a just transition to sustainability, where policies are designed and implemented with an acute awareness of their social implications.

5.2 Discussion of the findings in the context of existing literature

This section is aimed at comparing the thesis findings with existing research, particularly in terms of the distributional effects of LEZs in Barcelona. By revisiting the studies discussed in the literature review, it is examined how and whether the findings support or challenge previous research. Additionally, this section aims to highlight the distinctive contributions of this thesis to the wider academic discourse about how city policies like LEZs impact society and the economy.

The findings of this thesis can be easily situated within a well-curated landscape of existing research. First of all, what the interviews with experts confirm, as well as the fact that this research never tried to contradict this, is the critical role of LEZs in urban environmental management. It aligns with foundational studies that document the effectiveness of LEZs in reducing vehicular emissions and improving air quality in urban centres across Europe. Drawing from the works of scholars such as Morfeld et al. (2014), Bernardo et al. (2021), Zhai & Wolf (2021), and Rodriguez Ray (2022), this research echoes the consensus that LEZs, as a regulatory measure, contribute significantly to air pollution reduction.

However, this thesis contributes to an emerging body of literature that scrutinises the socio-economic dimensions of such environmental policies. By focusing on the LEZ policy in Barcelona, a case study is offered that reveals the nuanced impacts of LEZs on different socio-economic groups, a critical perspective that is less explored in existing studies. This approach resonates with the calls from researchers like De Vrij & Vanoutrive (2022) for more nuanced analyses of environmental justice that consider not only the environmental but also the social outcomes of urban policies.

Moreover, the findings critically expand the dialogue around environmental justice, emphasising that while LEZs are effective in improving air quality, they may inadvertently perpetuate or even exacerbate socio-economic inequalities. This assertion is particularly powerful in the context of Barcelona, where disparities in income and access to transportation options can significantly influence residents' experiences when it comes to complying with LEZ regulations. These findings support the observations made by Verbeek & Hicks (2022) in their research, where they conclude that in the case of London, the LEZ policy has an especially negative impact on the poorer areas with the worst public transport quality.

The qualitative component of this thesis, encompassing surveys and interviews, offers invaluable insights into the real-world experiences of LEZ policy impacts in Barcelona. This approach highlights the significance of including a variety of stakeholder perspectives in policy evaluation, echoing the principles championed by environmental justice scholars such as Gatta & Marcucci (2016). Thus, it enriches theoretical debates on participatory governance and underscores the necessity of inclusive policymaking processes. Furthermore, this qualitative inquiry unveils the nuanced distributional effects of the LEZ policy, which might remain obscured by broader quantitative analyses that overlook specific instances. This aspect is particularly evident when contrasting the findings of this thesis with those of Rius et al. (2022), co-authored by Núria Pérez and David Andrés. Their research suggests that the LEZ's impacts are minimal and not disproportionately borne by low-income populations. However, the comprehensive analysis, blending both qualitative and quantitative methods, reveals a different picture: low-income households do indeed experience the policy's effects more severely. This discrepancy underscores the importance of a mixed-methods approach in capturing the full spectrum of the LEZ's socioeconomic implications, thereby contributing to a more equitable policy formulation.

Furthermore, another finding of this thesis further supported by existing academic literature is the importance of taking political ideology as well as subjective public perception into account when analysing the overall opinion and satisfaction of the population with sustainable policies, particularly the LEZ policy in Barcelona. This aligns well with the statements made by Morton et al. (2021) and Oltra et al. (2020) about the fundamental role that attitudes, views about particular policies, confidence in the government, and problem awareness all play in terms of public policy acceptance. Nonetheless, it is important to highlight the differences between the findings of Oltra et al. (2020) and this thesis regarding the LEZ policy's level of acceptance and overall satisfaction in Barcelona. Oltra et al. report a generally positive acceptance among the city's residents, in stark contrast to the negative perceptions uncovered in the qualitative survey performed in this study. This discrepancy aligns more closely with the findings of Amorim-Maia et al. (2023), who also report negative sentiments towards the LEZ policy. The variation in findings may stem from differences in sample populations. Oltra et al. acknowledge their sample's bias towards younger and more educated individuals, possibly contributing to the more favourable views on the policy. Conversely, this thesis utilises a smaller, more targeted sample, including right-leaning individuals from Pedralbes and those with lower education levels and

incomes in Ciutat Meridiana, offering a plausible explanation for the lower acceptance and satisfaction with the LEZ observed in this This emphasises the significance of diverse and representative sampling to capture varied perceptions across different demographics, highlighting how factors such as age, education level, political orientation, and socio-economic status can influence policy acceptance. The acknowledgment of sample bias in studies and the contrasting findings between different research efforts underscore the complexity of assessing policy acceptance and satisfaction.

Moreover, this thesis navigates the complex interplay between urban development, sustainability, and social equity, contributing to a growing discourse on sustainable urban transitions. By presenting Barcelona's LEZs within a broader socio-economic context, this research challenges the conventional wisdom that environmental policies are inherently neutral. Instead, this research advocates for a holistic view of urban sustainability, one that encompasses economic, social, and environmental dimensions, aligning with Pereira et al. (2016) and Bannister (2018)

Finally, building upon the detailed empirical insights and their comparison with existing literature, the attention turns to a critical examination of how the outcomes of LEZ policies in Barcelona resonate with the theoretical frameworks of justice and capability as proposed by Rawls and the capabilities approach. This discussion aims to bridge the gap between empirical findings and philosophical principles, shedding light on the ethical dimensions of environmental policy implementation. The thesis results, particularly in the context of Rawls' theory of justice and the capabilities approach, underscore a nuanced perspective on the socio-economic impacts of LEZ policies in Barcelona. Drawing upon the Rawlsian principle of fairness and the capabilities approach's emphasis on enabling individuals to lead lives they value; this thesis critically examines the distributive effects of LEZ policies. It reveals that while LEZs aim to improve air quality—a goal aligned with Rawls' emphasis on equitable benefit distribution—the actual outcomes may not fully support the enhancement of capabilities across all socio-economic groups, particularly low-income households. The thesis findings suggest that despite the intentions of LEZ policies to distribute environmental benefits fairly, the capacity of lower-income groups to adapt to these policies is constrained, thereby limiting their capabilities in ways that Rawlsian and capability frameworks would deem unjust. This highlights the necessity for policy designs that not only aim for environmental sustainability but also ensure that the benefits of such policies are accessible to all individuals, thereby fostering a more inclusive form of urban development that aligns with the ideals of justice, fairness, and the enhancement of capabilities.

In conclusion, this research contributes to a growing body of literature calling for a more equitable approach to urban environmental governance, concretely in the adaptation of the LEZ policy in Barcelona, where the benefits of cleaner air are shared by all residents without amplifying the difficulties low-income households have to deal with.

5.3 Reflection on the research approach: validity and limitations

After carefully reviewing and discussing the thesis results on the distributional effects of the LEZ policy in Barcelona, it's clear that the study provides significant insights into the distributional effects. However, like all research, it comes with its own set of limitations and considerations regarding its validity. Here, the research's validity and limitations are discussed.

Research Validity

This thesis employs a robust methodological framework, incorporating both quantitative and qualitative analyses, to explore the distributional effects of LEZ policies. This mixed-methods approach enhances the validity of the findings as it allows for the triangulation of data, offering a comprehensive view of the LEZ's effects on different socio-economic groups within Barcelona. The statistical correlation analysis provides empirical evidence of the distributional effects, while the qualitative surveys add depth by capturing the lived experiences of affected residents.

Moreover, the validation step involving semi-structured interviews with mobility experts further strengthens the study's internal validity. By discussing the findings with experts, it is not only ensured that the interpretations are grounded in the realities of urban mobility and policy impacts but also adds a layer of professional scrutiny to the analysis. The experts confirmed the overall reliability of the methods used as well as the results presented in this thesis, but they also offered valuable feedback on specific aspects, enriching the discussion and offering suggestions and recommendations for refining the research further.

Limitations

One of the primary limitations of this thesis is its geographic and demographic scope. Referring back to the methodology, a strong rationale is used to justify doing an embedded single CSA of the LEZ policy in Barcelona. Nonetheless, it is recognised that this focus exclusively on Barcelona, while providing in-depth insights into the city's context, may limit the generalizability of the findings to other urban areas with different socio-economic landscapes or LEZ configurations. Urban dynamics and policy impacts can vary significantly across different cities, influenced by local governance structures, economic conditions, and cultural attitudes towards transportation and environmental policies (Gustafsson, 2017).

In regards to the statistical correlation study, it's important to balance the insights gained from aggregated data with an understanding of its limitations, as it does not show disparities within units of analysis. However, the incorporation of qualitative research makes it possible to capture a fuller picture of the impacts at a more granular level.

Finally, another clear limitation of this thesis is the sample size in the qualitative surveys. While the surveys offer valuable perspectives on the personal experiences of residents in two neighbourhoods, the extent to which these findings can be extrapolated to the broader population of the neighbourhoods or similar urban settings may be limited. However, it is important to remark once again the high segregation of these neighbourhoods, which leads to the belief that the sample size, although small, might be more representative than in other cases. This is supported by mobility expert Núria Pérez. Nonetheless, there is a consensus between the mobility experts interviewed and academic literature on the fact that the representativeness of the sample when carrying out qualitative surveys is crucial for the external validity of the research findings (Taherdoost, 2017), which sustains the argument that the qualitative surveys performed for this thesis could have benefited from a larger population sample.

In order to address these limitations and enhance the validity of future research, several strategies can be employed. Expanding the geographic scope to include multiple cities with LEZ policies would provide comparative data, enriching the understanding of LEZ impacts across different urban contexts. This would also help to assess the generalizability of the findings. On the other hand, increasing the sample size of the qualitative survey could improve the representativeness of the data.

In general, this thesis makes a significant contribution to the understanding of the socio-economic impacts of LEZ policies in urban areas. The methodological rigour and the mixed-methods approach enhance the validity of the findings, providing valuable insights into the distributional effects of environmental policies. However, recognising the limitations inherent in the study's scope and sampling strategy is crucial for interpreting the findings and guiding future research. Addressing these limitations in subsequent studies can further refine the understanding of the complex interplay between urban environmental policies, socio-economic equity, and sustainable urban development.

6 Conclusion, policy recommendations and future research

6.1 Conclusion

This thesis underscores the imperative of integrating social justice within the sustainability agenda, particularly in urban settings where the impacts of climate policies such as LEZs are most acutely felt. There has been a growing consensus amongst the academic community on the need for a 'just transition' that harmonises environmental sustainability with social equity, despite the acknowledged challenges in bridging the gap between aspiration and realisation. This sets the stage for a nuanced investigation into how urban climate policies, specifically LEZs, can be designed and implemented to mitigate environmental impacts without exacerbating social inequalities.

Addressing the knowledge gap, a lack of comprehensive studies examining how principles of social justice are integrated into real-world sustainability initiatives is identified, particularly in the urban context. Therefore, this thesis articulates a critical need for empirical research to understand the distributional effects of urban environmental policies like LEZs on social justice. This research intends to contribute to closing this gap by providing empirical insights into the distributional effects of Barcelona's LEZ policy. By focusing on this specific urban environmental policy, the thesis seeks to illuminate the complexities of ensuring that efforts to combat climate challenges also advance social justice, thereby offering a significant contribution to the broader discourse on sustainable and equitable urban development. To do so, the research project seeks to answer the following research question:

"***What are the distributional effects of Barcelona's LEZ policy and what lessons can be derived in order to adopt better practices on the implementation of the LEZ policies?"***

To address the overarching question and its related sub-questions, this study employed an embedded single-case study design, with Barcelona's LEZ policy as the focal point to scrutinise its distributional impacts across diverse socioeconomic groups. Barcelona's unique geographical and sociopolitical landscape offered a rich context for in-depth analysis, yielding insights into the policy's distributional effects and, by extension, shedding light on the broader implications of LEZs. The research methodology integrated both quantitative and qualitative strategies, including statistical correlation analysis, a qualitative survey, and interviews with four mobility experts, ensuring a comprehensive understanding of the phenomenon. This multifaceted approach, coupled with data triangulation, significantly enhanced the study's internal validity, allowing for a nuanced examination of the LEZ policy's social justice implications.

The main finding of the thesis's analysis of Barcelona's LEZ policy reveals nuanced distributional effects, highlighting that while a minority of Barcelona and MAB residents experience adverse impacts, these are significant. The correlational statistical analysis, the qualitative interviews carried out in Pedralbes and Ciutat Meridiana, and the expert interviews underscore the policy's uneven burdens, particularly on lower-income communities. The findings indicate that while the LEZ policy contributes to environmental improvements, its effects are not uniformly felt across the population. Particularly, lower-income groups face challenges in adapting to the policy, especially when they live in areas with poor public transport quality.

The findings advocate for a more equitable approach to LEZ implementation, stressing the importance of enhancing accessibility and reducing economic strain for the most affected. These recommendations primarily address distributional justice by seeking to ensure that the benefits and burdens of LEZ policies are shared more equitably among different socio-economic groups.

Nonetheless, beyond the significance of distributional justice in the implementation of urban climate policies like LEZs, this thesis also emphasises the crucial role of procedural justice. Procedural justice concerns the fairness and transparency of the processes by which decisions are made, ensuring that all stakeholders, particularly marginalised and disadvantaged groups, have a voice in the policymaking process. This is critical because the success of LEZs not only depends on their environmental outcomes but also on public understanding of the policy, acceptance, and perception of fairness in its implementation. Inclusive decision-making processes that engage a wide range of stakeholders can enhance the legitimacy and effectiveness of LEZ policies. By integrating both distributional and procedural justice, urban climate policies, specifically LEZ policies, can achieve their environmental objectives while also fostering social cohesion and equity, ensuring that the transition towards sustainability is both just and inclusive.

Additionally, the research findings also conclude that addressing the burdens on low-income populations necessitates a holistic view that extends beyond transport inequality to include systemic issues and the cumulative effects of various policies. It's crucial to recognise that challenges faced by these communities are not isolated to transport accessibility but are intertwined with broader urban policy areas. Integrating LEZ and transport policies with comprehensive urban planning, including considerations for housing prices, employment opportunities, and social infrastructure, can mitigate unintended consequences. This holistic approach ensures that policies do not inadvertently deepen existing inequalities but rather contribute to a more equitable and inclusive urban environment.

Finally, the significance of this research lies in its contribution to the ongoing debate on urban environmental policies and social justice. It underscores the necessity of developing LEZ policies that are sensitive to the distributional effects and the potential burdens they impose on vulnerable populations. In the following section, the recommendations provided aim to guide the implementation of more inclusive and equitable LEZ policies in urban areas, ensuring that efforts to improve air quality do not exacerbate social inequalities.

6.2 Policy Recommendations

Based on the findings and conclusions from the thesis on the distributional effects of the LEZ policy in Barcelona, this chapter proposes policy suggestions to improve the LEZ policy implementation and outlines directions for future research, incorporating expert suggestions alongside a review of existing literature and general knowledge. These recommendations and suggestions aspire to contribute to the development of more sustainable, inclusive, and effective urban environments.

Improving the implementation of LEZ policies in general and also in the specific case of Barcelona requires a comprehensive and inclusive approach that not only addresses environmental concerns but also considers the socioeconomic impacts on the city's residents. The following extended discussion elaborates on various policy suggestions that could potentially enhance the effectiveness and equity of LEZ.

The first suggestion consists of the possibility of **incorporating size and weight criteria into LEZ policies**. Doing so could further refine the approach to vehicle restrictions, acknowledging that the size and weight of vehicles significantly contribute to their environmental impact. Integrating these criteria into the eligibility for entry into LEZs ensures that larger, heavier vehicles, which typically emit more pollutants and take up more space, are regulated more stringently (Kemp et

al., 2020). Tailoring restrictions not just based on emissions but also on physical dimensions encourages the use of smaller, more efficient vehicles. Moreover, it enhances the equity of LEZ restrictions by also taking into account the typical ownership patterns of larger and heavier vehicles. Although the relationship between car size and wealth is not straightforwardly documented in all sources, there are indications that wealthier individuals may opt for larger vehicles, as they offer enhanced safety, comfort, and status (Soltani, 2017). Therefore, the policy can distribute the responsibility for environmental impact more evenly across different socio-economic groups.

A second recommendation that is important both in the general context of implementing LEZ policies and in the particular case of Barcelona is implementing **equitable vehicle replacement programmes.** These programmes could help ensure that LEZ policies do not disproportionately impact low-income households. Reflecting on the insights shared by Toon Meelen during his interview, it becomes clear that the electric car market, as it currently stands, offers limited equity (Hardman et al., 2021). To address this issue, it is essential to implement targeted subsidy programmes designed to support low-income households in transitioning away from non-compliant vehicles. By doing so, the financial strain on individuals and families least capable of affording newer, environmentally compliant vehicles can be significantly reduced. Such programmes should be accessible and generous enough to make a significant difference, offering a tangible path for individuals to contribute to cleaner air without facing financial hardship (Posada et al., 2015; Rubin & St. Louis, 2016). These programmes must be meticulously designed to align with the unique needs and contexts of the cities in which they are being implemented. Recognising and accommodating the distinct circumstances of each community can significantly enhance the effectiveness and acceptance of such initiatives. Tailoring support mechanisms to local conditions not only ensures that interventions are relevant and impactful but also fosters a sense of ownership and participation among community members.

Enhanced public transportation is also crucial for providing viable alternatives to private vehicle use, especially for lower-income residents who may rely more on public transport. Investing in the accessibility, frequency, and coverage of public transportation within and around LEZ areas can make it easier for people to choose public over private transport (De Oña, 2022). Although public transport quality in Barcelona is very high in most neighbourhoods, the statistical analysis carried out in this thesis shows that there are areas that could benefit from improvement, such as Ciutat Meridiana. Improvements could include extending service hours, increasing the number of routes that penetrate deeply into residential areas, and enhancing comfort and affordability. In the particular case of Barcelona, there are already some initiatives in place, concretely in the neighbourhood of Ciutat Meridiana. A bus on demand was implemented at the end of 2022 as a result of the successful trial carried out by the initiative “Pla de Barris 2021-2024”, which translates to “plan of neighbourhoods”.

Moreover, **community engagement and awareness** efforts are essential for the success of LEZ policies. This recommendation is linked to Dick Ettema’s suggestion to pay more attention to procedural justice. Increasing efforts to engage communities through informational campaigns and participatory decision-making processes ensures that residents are well-informed about LEZ policies and their benefits. This engagement should go beyond merely disseminating information; it should involve communities in meaningful ways that allow them to voice their

concerns, suggestions, and preferences. Building a sense of ownership and collaboration can enhance support for LEZ initiatives and lead to more effective implementation (Bernauer et al., 2016; Madumere, 2017; Khatibi et al., 2021). In the particular case of Barcelona, by engaging the community further, situations of the unawareness of the existence of exemptions that were prevalent both in Pedralbes and in the bus, especially in Ciutat Meridiana, could be prevented.

Another general recommendation that could lead to better implementation of LEZ policies is to perform periodic **comprehensive impact assessments,** which are necessary to evaluate the environmental and socio-economic effects of LEZ policies. Periodic evaluations focusing on the effects and outcomes of LEZ policies can inform policymakers about the effectiveness of current strategies and highlight areas for improvement. These assessments should consider a wide range of indicators, from air quality and greenhouse gas emissions to economic impacts on local businesses and the mobility of disadvantaged groups. In the particular case of Barcelona, this is especially important as the regulations tighten, as David highlighted during the interview. Although a quite detailed impact assessment on the socio-economic effects of Barcelona's LEZ was performed (Rius et al, 2021), periodic and updated impact assessments are necessary. The insights gained can guide adjustments to LEZ policies, ensuring they achieve environmental goals without exacerbating social inequalities (Moreno et al., 2022).

Finally, as it has been mentioned in the conclusion above, the **integration of LEZ initiatives with broader urban policies** is essential for achieving a holistic approach to urban development and sustainability. In alignment with insights from four mobility experts interviewed, incorporating LEZ policies within the wider framework of urban planning and sustainability strategies can significantly enhance their benefits and mitigate potential drawbacks. Among the innovative approaches discussed, Núria's proposal for implementing an urban toll that charges for private transport mobility emerges as a compelling strategy to promote more equitable and sustainable transport policies. This suggestion underscores the importance of integrating diverse mobility solutions to address urban environmental challenges comprehensively. Furthermore, considering how LEZs interact with other urban initiatives, such as greening projects, sustainable transportation modes, and housing policies, is crucial for creating a cohesive and sustainable urban environment**.** By viewing LEZs within the larger context of city development, these can work towards a future that is environmentally sustainable and socially just.

Implementing these recommendations requires careful planning, collaboration across different sectors, and a commitment to equitable and sustainable urban development. Through such a multifaceted approach, the implementation of LEZ policies can be enhanced, making them more effective, equitable, and supportive of the city's broader sustainability goals.

6.3 Suggestions for future research

To enhance the efficacy of LEZ policy recommendations in Barcelona and beyond, both policymakers and the academic community would benefit from expanded research aimed at refining these initiatives. Recognising the limitations previously mentioned, conducting comparative studies across various cities could unearth best practises and valuable lessons, offering insights into how successful policies can be adapted to different urban contexts. Furthermore, there's a notable need to delve deeper into the socio-economic impacts of LEZs, with a particular emphasis on their effects on vulnerable populations, aiming to design policies that mitigate adverse outcomes for these groups. Investigating the behavioural responses and

adjustments of individuals and businesses to LEZ policies will also shed light on the policy's broader implications, including changes in transportation habits, vehicle ownership, and lifestyle adaptations. Additionally, exploring the potential of technological innovations, such as electric vehicles and smart mobility solutions, remains a critical and dynamic area of research that could significantly enhance the adaptability of LEZs.

This thesis concludes on a note of hopeful pragmatism, acknowledging the challenges inherent in integrating social justice with environmental sustainability yet affirming the potential for impactful change. Through the lens of Barcelona's LEZ policy, this thesis sheds light on a path for developing urban policies that genuinely reflect the principles of equity and inclusion. As the urban sustainability journey moves forward, it is important that these findings encourage a bigger shift in how cities approach their environment, ensuring that the pursuit of clean air and green cities does not sideline the voices and needs of the most vulnerable. In doing so, it is aspired to create not just sustainable urban environments but just and equitable spaces where all residents have the opportunity to thrive.

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Appendix I – Quantitative Data used for statistic correlation analysis

Table 7. GDHI index of MAB municipalities, classified as l*ow, medium and high-income*

Municipality	GDHI per inhabitant. Catalunya index = 100	Municipality	GDHI per inhabitant. Catalunya index = 100
Badia del Vallès	75.2	Santa Coloma de Cervelló	107
Santa Coloma de Gramenet	81.1	Gavà	107.7
Sant Adrià de Besòs	84.5	Cerdanyola del Vallès	108.3
Hospitalet de Llobregat, l'	87.3	Sant Feliu de Llobregat	108.5
Ripollet	90.3	Montgat	109.2
Montcada i Reixac	90.8	Torrelles de Llobregat	109.2
Badalona	93	Cervelló	110.8
Sant Vicenç dels Horts	93	Pallejà	111
Sant Andreu de la Barca	93.1	Palma de Cervelló, la	112
Cornellà de Llobregat	93.8	Sant Joan Despí	112.1
Sant Boi de Llobregat	96.1	Molins de Rei	112.3
Viladecans	97.6	Esplugues de Llobregat	116.7
Prat de Llobregat, el	97.8	Castelldefels	117.3
Barberà del Vallès	99.8	Begues	121.2
Sant Climent de Llobregat	100.9	Tiana	135.1
Papiol, el	101.1	Sant Cugat del Vallès	143.3
Castellbisbal	102.7	Sant Just Desvern	152.5
Corbera de Llobregat	106.5		

Table 8. DHI index of Barcelona neighbourhoods, classified as low, medium and high-income neighbourhoods of Barcelona

Barcelona neighbourhoods	GDHI per inhabitant. Catalunya index = 1.00 2019	Barcelona neighbourhoods	GDHI per inhabitant. Catalunya index = 1.00 2019
Ciutat Meridiana	0.48	Provençals del Poblenou	0.9
Torre Baró	0.52	la Font de la Guatlla	0.91
Vallbona	0.52	Can Baró	0.91
la Trinitat Vella	0.54	Navas	0.92
Baró de Viver	0.54	el Clot	0.92
el Raval	0.55	el Camp de l'Arpa del Clot	0.94
la Trinitat Nova	0.55	el Coll	0.96
la Marina del Prat Vermell - AEI Zona Franca	0.56	el Guinardó	0.96
Can Peguera	0.57	el Parc i la Llacuna del Poblenou	0.96
el Besòs i el Maresme	0.58	Sant Andreu	0.97
les Roquetes	0.59	Sants	0.98
Verdun	0.64	el Baix Guinardó	0.98
el Turó de la Peira	0.65	la Sagrada Família	1.02
el Bon Pastor	0.69	la Vall d'Hebron	1.02
el Carmel	0.7	el Poblenou	1.02
la Prosperitat	0.71	Sant Antoni	1.03
la Barceloneta	0.73	el Fort Pienc	1.04
el Poble Sec - AEI Parc de Montjuïc	0.73	la Vila de Gràcia	1.07
el Barri Gòtic	0.75	la Salut	1.12
la Marina de Port	0.76	la Font d'en Fargues	1.12
Porta	0.76	Nova Esquerra de l'Eixample	1.14
la Verneda i la Pau	0.76	el Camp d'en Grassot i Gràcia Nova	1.14
la Teixonera	0.77	Diagonal Mar i el Front Marítim del Poblenou	1.15
Sant Genís dels Agudells	0.78	Vallcarca i els Penitents	1.17
Canyelles	0.8	la Maternitat i Sant Ramon	1.19
Sant Pere, Santa Caterina i la Ribera	0.81	Antiga Esquerra de l'Eixample	1.24
Sant Martí de Provençals	0.84	les Corts	1.3
la Guineueta	0.85	Vallvidrera, el Tibidabo i les Planes	1.32
Montbau	0.86	la Dreta de l'Eixample	1.36
la Clota	0.87	el Putxet i el Farró	1.39
Vilapicina i la Torre Llobeta	0.87	la Vila Olímpica del Poblenou	1.46
Hostafrancs	0.89	Sarrià	1.62
Sants - Badal	0.89	Sant Gervasi - la Bonanova	1.66
la Sagrera	0.89	Sant Gervasi - Galvany	1.68
la Bordeta	0.9	Pedralbes	1.76
Horta	0.9	les Tres Torres	1.89
el Congrés i els Indians	0.9		

Table 9. GDHI index and % of non-compliant cars in MAB municipalities

Municipality	GDHI per inhabitant. Catalunya index = 100 2020	Non-compliable cars (%) (2022)	Municipality	GDHI per inhabitant. Catalunya index = 100 2020	Non-compliable cars (%) (2022)
Palma de Cervelló, la	112	16.63	Gavà	107.7	25.41
Sant Joan Despí	112.1	20.79	Esplugues de Llobregat	116.7	25.69
Montgat	109.2	21.72	Sant Climent de Llobregat	100.9	25.86
Santa Coloma de Cervelló	107	21.99	Montcada i Reixac	90.8	26.22
Pallejà	111	22.40	Prat de Llobregat, el	97.8	26.22
Sant Cugat del Vallès	143.3	22.62	Hospitalet de Llobregat, l'	87.3	26.27
Tiana	135.1	22.77	Sant Andreu de la Barca	93.1	26.35
Sant Feliu de Llobregat	108.5	23.28	Cervelló	110.8	26.78
Begues	121.2	23.36	Castelldefels	117.3	27.22
Sant Just Desvern	152.5	23.91	Torrelles de Llobregat	109.2	27.68
Cerdanyola del Vallès	108.3	24.09	Santa Coloma de Gramenet	81.1	27.73
Cornellà de Llobregat	93.8	24.29	Corbera de Llobregat	106.5	27.86
Molins de Rei	112.3	24.33	Sant Adrià de Besòs	84.5	28.10
Sant Boi de Llobregat	96.1	24.70	Sant Vicenç dels Horts	93	28.49
Viladecans	97.6	24.79	Badalona	93	29.09
Castellbisbal	102.7	24.92	Papiol, el	101.1	29.53
Ripollet	90.3	24.96	Badia del Vallès	75.2	29.94
Barberà del Vallès	99.8	25.01			

Table 10. GDHI index and % of non-compliant cars in Barcelona neighbourhoods

Barcelona neighbourhoods	GDHI per inhabitant. Catalunya index = 1.00 2019	Non-compliable cars (%) (2019)	Barcelona neighbourhoods	GDHI per inhabitant. Catalunya index = 1.00 2019	Non-compliable cars (%) (2019)
Diagonal Mar i el Front Marítim del Poblenou	1.15	16.82	el Putxet i el Farró	1.39	25.39
Sant Pere, Santa Caterina i la Ribera	0.81	19.99	la Teixonera	0.77	25.55
la Vila Olímpica del Poblenou	1.46	20.81	la Font de la Guatlla	0.91	25.55
Sant Andreu	0.97	22.46	Sants	0.98	25.58
Provençals del Poblenou	0.9	22.47	el Camp de l'Arpa del Clot	0.94	25.59
les Corts	1.3	22.69	Montbau	0.86	25.65
la Vall d'Hebron	1.02	22.80	Porta	0.76	25.66
el Clot	0.92	23.01	Can Baró	0.91	25.68
el Poblenou	1.02	23.06	la Verneda i la Pau	0.76	25.71
Nova Esquerra de l'Eixample	1.14	23.14	Antiga Esquerra de l'Eixample	1.24	25.86
el Bon Pastor	0.69	23.21	el Barri Gòtic	0.75	26.04
la Sagrera	0.89	23.28	Sant Antoni	1.03	26.08
la Guineueta	0.85	23.40	Sant Genís dels Agudells	0.78	26.09
el Parc i la Llacuna del Poblenou	0.96	23.74	Sant Gervasi - Galvany	1.68	26.15
la Font d'en Fargues	1.12	23.82	Canyelles	0.8	26.46
Vilapicina i la Torre Llobeta	0.87	24.03	Pedralbes	1.76	26.48
el Coll	0.96	24.22	la Barceloneta	0.73	26.65
la Marina de Port	0.76	24.23	Baró de Viver	0.54	26.88
la Bordeta	0.9	24.37	el Carmel	0.7	27.23
el Fort Pienc	1.04	24.40	Vallvidrera, el Tibidabo i les Planes	1.32	27.31
Sant Martí de Provençals	0.84	24.42	la Prosperitat	0.71	27.77
Navas	0.92	24.43	la Dreta de l'Eixample	1.36	28.05
el Camp d'en Grassot i Gràcia Nova	1.14	24.48	Hostafrancs	0.89	28.36
la Sagrada Família	1.02	24.51	la Vila de Gràcia	1.07	28.48
el Congrés i els Indians	0.9	24.58	Verdun	0.64	28.52
la Salut	1.12	24.68	Can Peguera	0.57	29.06
el Baix Guinardó	0.98	24.73	el Besòs i el Maresme	0.58	29.32
les Tres Torres	1.89	24.74	el Poble Sec - AEI Parc de Montjuïc	0.73	29.49
Horta	0.9	24.78	la Marina del Prat Vermell - AEI Zona Franca	0.56	30.87
Sant Gervasi - la Bonanova	1.66	24.80	la Trinitat Nova	0.55	31.50
Sants - Badal	0.89	24.82	la Trinitat Vella	0.54	31.85
la Clota	0.87	24.93	les Roquetes	0.59	31.86
Vallcarca i els Penitents	1.17	24.99	Ciutat Meridiana	0.48	32.56
el Guinardó	0.96	25.00	el Raval	0.55	34.47
la Maternitat i Sant Ramon	1.19	25.31	Vallbona	0.52	37.69
el Turó de la Peira	0.65	25.34	Torre Baró	0.52	38.87
Sarrià	1.62	25.39			

Table 11. Public Transport quality of MAB Municipalities

Municipality	Time by car to Pl. Catalunya (min)	Time by public transport to Pl. Catalunya (min)	Public Transport quality	Municipality	Time by car to Pl. Catalunya (min)	Time by public transport to Pl. Catalunya (min)	Public Transport quality
Palma de Cervelló, la	33	42	GOOD	Gavà	26	30	GOOD
Sant Joan Despí	27	17	GOOD	Esplugues de Llobregat	24	29	GOOD
Montgat	23	23	GOOD	Sant Climent de Llobregat	32	52	POOR
Santa Coloma de Cervelló	30	41	POOR	Montcada i Reixac	27	20	GOOD
Pallejà	29	46	POOR	Prat de Llobregat, el	23	23	GOOD
Sant Cugat del Vallès	31	61	POOR	Hospitalet de Llobregat, l'	23	12	GOOD
Tiana	26	44	POOR	Sant Andreu de la Barca	37	46	GOOD
Sant Feliu de Llobregat	31	21	GOOD	Cervelló	34	75	POOR
Begues	39	78	POOR	Castelldefels	31	34	GOOD
Sant Just Desvern	30	38	GOOD	Torrelles de Llobregat	38	57	POOR
Cerdanyola del Vallès	26	32	GOOD	Santa Coloma de Gramenet	21	25	GOOD
Cornellà de Llobregat	15	25	GOOD	Corbera de Llobregat	35	48	POOR
Molins de Rei	29	27	GOOD	Sant Adrià de Besòs	23	15	GOOD
Sant Boi de Llobregat	28	38	POOR	Sant Vicenç dels Horts	28	40	POOR
Viladecans	28	29	GOOD	Badalona	24	20	GOOD
Castellbisbal	31	78	POOR	Papiol, el	32	46	POOR
Ripollet	33	44	POOR	Badia del Vallès	37	44	GOOD
Barberà del Vallès	33	30	GOOD				

Table 12. Public Transport quality of MAB Municipalities

Neighbourhood	Time by car to Pl. Catalunya (min)	Time by public transport to Pl. Catalunya (min)	Public Transport quality	Neighbourhood	Time by car to Pl. Catalunya (min)	Time by public transport to Pl. Catalunya (min)	Public Transport quality
Torre Baró	28	20	GOOD	el Turó de la Peira	24	25	GOOD
Vallbona	27	26	GOOD	la Maternitat i Sant Ramon	21	26	GOOD
el Raval	8	8	GOOD	el Guinardó	20	24	GOOD
Ciutat Meridiana	28	35	POOR	Vallcarca i els Penitents	20	18	GOOD
les Roquetes	25	27	GOOD	la Clota	22	25	GOOD
la Trinitat Vella	25	24	GOOD	Sants - Badal	15	14	GOOD
la Trinitat Nova	23	25	GOOD	Sant Gervasi - la Bonanova	21	18	GOOD
la Marina del Prat Vermell -	18	43	POOR	Horta	20	24	GOOD
el Poble Sec - AEI Parc de M	11	9	GOOD	les Tres Torres	16	12	GOOD
el Besòs i el Maresme	21	22	GOOD	el Baix Guinardó	16	15	GOOD
Can Peguera	24	32	POOR	la Salut	17	17	GOOD
Verdun	24	27	GOOD	el Congrés i els Indians	17	20	GOOD
la Vila de Gràcia	13	12	GOOD	la Sagrada Família	14	11	GOOD
Hostafrancs	10	7	GOOD	el Camp d'en Grassot i Gràcia	12	16	GOOD
la Dreta de l'Eixample	6	7	GOOD	Navas	14	14	GOOD
la Prosperitat	22	28	POOR	Sant Martí de Provençals	16	20	GOOD
Vallvidrera, el Tibidabo i les	27	27	GOOD	el Fort Pienc	9	11	GOOD
el Carmel	21	18	GOOD	la Bordeta	10	17	POOR
Baró de Viver	21	27	GOOD	la Marina de Port	16	26	POOR
la Barceloneta	16	23	POOR	el Coll	19	23	GOOD
Pedralbes	21	39	POOR	Vilapicina i la Torre Llobeta	21	22	GOOD
Canyelles	23	22	GOOD	la Font d'en Fargues	23	41	POOR
Sant Gervasi - Galvany	11	10	GOOD	el Parc i la Llacuna del Pobler	14	13	GOOD
Sant Genís dels Agudells	24	22	GOOD	la Guineueta	23	24	GOOD
Sant Antoni	8	11	GOOD	la Sagrera	17	12	GOOD
el Barri Gòtic	22	7	GOOD	el Bon Pastor	21	30	POOR
Antiga Esquerra de l'Eixamp	7	9	GOOD	Nova Esquerra de l'Eixample	7	11	GOOD
la Verneda i la Pau	18	27	POOR	el Poblenou	17	14	GOOD
Can Baró	19	23	GOOD	el Clot	15	13	GOOD
Porta	23	24	GOOD	la Vall d'Hebron	21	18	GOOD
Montbau	22	18	GOOD	les Corts	20	21	GOOD
el Camp de l'Arpa del Clot	15	16	GOOD	Provençals del Poblenouu	19	27	POOR
Sants	12	11	GOOD	Sant Andreu	24	17	GOOD
la Font de la Guatlla	8	12	GOOD	la Vila Olímpica del Poblenou	16	17	GOOD
la Teixonera	22	17	GOOD	Sant Pere, Santa Caterina i la	9	12	GOOD
el Putxet i el Farró	14	12	GOOD	Diagonal Mar i el Front Marít	18	20	GOOD
Sarrià	20	25	GOOD				

Table 13. Percentage reduction of non-compliant cars in Barcelona neighbourhoods (2019 vs 2021)

Barcelona neighbourhoods	Non-compliable cars (%) (2019)	Non-compliable cars (%) (2021)	% reduction of non-compliable cars 2019 vs 2021	Barcelona neighbourhoods	Non-compliable cars (%) (2019)	Non-compliable cars (%) (2021)	% reduction of non-compliable cars 2019 vs 2021
la Marina del Prat Vermell - AEI Zona Franca	30.87	30.32	0.55	el Fort Pienc	24.40	18.14	6.27
Torre Baró	38.87	29.49	9.39	Sants - Badal	24.82	18.07	6.76
Vallbona	37.69	27.59	10.10	Can Baró	25.68	18.06	7.63
el Raval	34.47	25.71	8.76	la Sagrada Família	24.51	18.05	6.46
Ciutat Meridiana	32.56	23.80	8.76	Canyelles	26.46	18.05	8.42
la Trinitat Vella	31.85	23.06	8.79	la Teixonera	25.55	17.89	7.66
les Roquetes	31.86	22.56	9.30	el Camp d'en Grassot i Gràcia Nova	24.48	17.75	6.74
Pedralbes	26.48	22.47	4.01	Porta	25.66	17.72	7.94
la Dreta de l'Eixample	28.05	22.28	5.77	Nova Esquerra de l'Eixample	23.14	17.69	5.45
Vallvidrera, el Tibidabo i les Planes	27.31	21.90	5.41	Horta	24.78	17.55	7.23
Sant Gervasi - Galvany	26.15	21.84	4.31	Navas	24.43	17.52	6.90
el Poble Sec - AEI Parc de Montjuïc	29.49	21.77	7.72	les Corts	22.69	17.52	5.17
el Barri Gòtic	26.04	21.71	4.33	la Font d'en Fargues	23.82	17.51	6.31
la Trinitat Nova	31.50	21.65	9.85	la Verneda i la Pau	25.71	17.51	8.21
la Vila de Gràcia	28.48	21.65	6.83	el Guinardó	25.00	17.48	7.52
Can Peguera	29.06	21.16	7.91	la Bordeta	24.37	17.40	6.97
Hostafrancs	28.36	21.05	7.31	el Turó de la Peira	25.34	17.40	7.94
Sarrià	25.39	20.62	4.78	Sant Martí de Provençals	24.42	17.20	7.22
Sant Gervasi - la Bonanova	24.80	20.54	4.25	el Coll	24.22	17.12	7.10
les Tres Torres	24.74	20.46	4.28	el Bon Pastor	23.21	17.08	6.13
el Putxet i el Farró	25.39	20.20	5.19	Vilapicina i la Torre Llobeta	24.03	16.89	7.15
Verdun	28.52	20.13	8.40	Baró de Viver	26.88	16.76	10.12
Sant Antoni	26.08	20.02	6.06	Sant Genís dels Agudells	26.09	16.72	9.37
el Besòs i el Maresme	29.32	19.96	9.36	Montbau	25.65	16.58	9.07
Antiga Esquerra de l'Eixample	25.86	19.85	6.01	la Sagrera	23.28	16.57	6.71
la Prosperitat	27.77	19.72	8.05	Sant Pere, Santa Caterina i la Ribera	19.99	16.47	3.52
la Barceloneta	26.65	19.25	7.40	el Clot	23.01	16.39	6.62
el Carmel	27.23	19.01	8.22	el Congrés i els Indians	24.58	16.34	8.24
Vallcarca i els Penitents	24.99	18.91	6.09	Provençals del Poblenou	22.47	16.26	6.21
la Maternitat i Sant Ramon	25.31	18.89	6.42	el Parc i la Llacuna del Poblenou	23.74	16.14	7.59
el Camp de l'Arpa del Clot	25.59	18.88	6.70	la Guineueta	23.40	16.05	7.35
Sants	25.58	18.58	7.00	Sant Andreu	22.46	15.82	6.64
el Baix Guinardó	24.73	18.49	6.24	la Vila Olímpica del Poblenou	20.81	15.67	5.15
la Font de la Guatlla	25.55	18.37	7.18	la Vall d'Hebron	22.80	15.66	7.13
la Marina de Port	24.23	18.20	6.03	la Clota	24.93	15.52	9.41
la Salut	24.68	18.17	6.50	el Poblenou	23.06	15.12	7.94
				Diagonal Mar i el Front Marítim del Poblenou	16.82	12.22	4.60

Appendix II – Qualitative survey design

Survey Title: Barcelona Low Emission Zone Impact Assessment

Introduction: Hello! Thank you for participating in our survey. This survey aims to understand the experiences and perceptions of residents in different neighbourhoods of Barcelona regarding the implementation of the Low Emission Zone (LEZ) policy in 2019. Your feedback is crucial in helping us analyse the impact and distributional effects of the LEZ policy among lower and higher-income households. The main themes of the survey include policy awareness and understanding, social and community effects, economic impacts, adaptation strategies, and overall satisfaction, and they are distributed amongst seven sections of the survey.

* = Mandatory answer

Section 1: Awareness and understanding of LEZ

1.1. **Awareness:**

- Were you aware of the implementation of the LEZpolicy in Barcelona in 2019?
    - Yes
    - No

1.2. **Understanding:**

- How would you rate your understanding of the LEZ policy?
    - Very clear
    - Somewhat clear
    - Not clear at all

Section 2: Impact of LEZ on Daily Life

2.1 **Previous Reliance on Private Car:**

- Before the implementation of the LEZ policy, did you primarily rely on a private car for transportation?
    - Yes
    - No

2.2 **LEZ Standards Compliance:**

- If you relied on a private car before the implementation of the LEZ policy, did your car meet the emission standards set by the LEZ once it came into action?
    - Yes
    - No

2.3 **Vehicle Change :**

- Have you made any changes to your vehicle(s) due to the LEZ policy?

- Yes
- No

- If yes, please describe the changes or add your experiences:

2.4 **Transportation Mode :**

- Has the LEZ policy influenced your choice of transportation modes?
    - Yes
    - No
- If yes, please specify how:

Section 3: Financial and Social Impact

3.1. **Financial Impact:**

- Have you experienced any financial impact as a result of the LEZ policy?
    - Yes
    - No
- If yes, please elaborate:

3.2. **Social Impact:**

- Do you feel that the LEZ policy has had social implications in your neighbourhood, such as behavioural choices? Think if the routine of your family or people you know has changed or been affected by this rule?.
    - Yes
    - No
    - I don't know

Answers for Pedralbes : 50% No (7/14), 28.6% Yes (4/14), 21,4% I don't know (3/14)

Answers for Ciutat Meridiana: 60% Yes (6/10), 10% No (1/10), 30% I don't know (3/10)

- If yes, please share your observations :

Section 4: Awareness and usage of exemptions

4.1. **Awareness of exemptions**

- Are you aware of the exemptions and authorization system the policy offers?
    - Yes
    - No

4.2**. Usage of the exemptions/authorizations**

- Have you applied for or made use of these exemptions/authorizations?
    - Yes
    - No
- If yes, which ones ?

Section 5: Overall Satisfaction and Suggestions

5.1. **Satisfaction:**

- How satisfied are you with the overall implementation of the LEZ policy in your neighbourhood?
    - Very satisfied
    - Somewhat satisfied
    - Somewhat dissatisfied
    - Very dissatisfied

Section 6: Demographics

6.1 Gender *

- Male
- Female
- Other

6.2 Age *

- 18-25
- 26-60
- > 60

6.3 Income Level

- What is your approximate household income per capita?
    - Low-income (<15.000)
    - Middle-income (15.000 – 27.000)
    - High-income (>27.000)

Section 7. Suggestions and/or anything to add?

- What suggestions do you have to improve the impact and distributional effects of the LEZ policy, especially considering the differences in income levels between neighbourhoods?

Conclusion: Thank you for completing the survey! Your input is valuable in understanding the varied experiences of residents in different neighbourhoods regarding the Low Emission Zone policy.

Appendix III – Interview with experts

Title: INTERVIEW WITH EXPERTS

1st, open questions

1. Can you give me a brief explanation of your field of expertise related to mobility?
2. When you think about sustainable transport transitions in urban areas, what type of modal transport shifts do you envision?
3. Could you elaborate on your experience with LEZ and how you believe they impact urban mobility and environmental sustainability?
4. What do you know about the distributional effects and justice implications of sustainable mobility policies in general, but especially about LEZ policies?
5. Have you ever given any thought to how equitable the LEZ policies are? What is your view?

2nd, After looking at the results of my quantitative study

6. How well do you think these results reflect the reality of the distributional effects of LEZ to your knowledge?

3rd, After looking at preliminary outcomes of the survey

7. What insights can you give about the results I got from the surveys in one of the poorer and richest neighbourhoods in Barcelona?

4th: Additional monitoring of distributional effects

8. What additional factors or indicators, not accounted for in this study, do you consider pivotal in influencing inequalities related to LEZ (LEZs)?
9. How can ongoing monitoring and evaluation be used to make adjustments and ensure that the implementation remains equitable?

5e Personal opinion on LEZ Policy

10. According to your knowledge, would you consider LEZ policy to be a generally fair solution to transitioning to more sustainable transport and healthier cities?

6th: Enhancing equality

11. What strategies can be employed to minimise any negative impact on vulnerable or marginalised communities?
12. How can low-income individuals and communities be included in the transition to cleaner transportation technologies within the context of LEZs?