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Traffic pollution as a privilege: An intersectional approach to environmental justice and transport emissions

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A R T I C L E I N F O

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A B S T R A C T

The growing concern over air pollution and community health, demands a comprehensive understanding of the political nature of transport-related emissions. This paper approaches how structures of power influence travel behaviour and, consequently, how they shape emissions from mobility in Barcelona. To comprehend how the intersection of gender, age, and migration background influences air pollution, we use a travel survey to build a set of models that are known to theoretically engage with intersectionality studies. Results show that identities tied to structures of power promote a greater contribution to air pollution than other mechanisms. That is, middle-aged European-born men have the most NO_x-intensive mobility practices. In contrast, people that embody intersectional experiences of oppression such as misogyny, racism, or ageism, have lower emission levels. Considering these results, we argue that policies which acknowledge the unequal distribution of responsibilities present an opportunity to reduce emissions from transportation, while guaranteeing fairness and advancing environmental justice.

1. Introduction

Despite the fact that air pollution and air quality are often considered to be the largest threats to global public health (WHO, 2023), the atmosphere is rarely regarded as a political space where power dynamics, governance structures, and inequalities intersect (Allen, 2020; Graham, 2015). A conceptualisation of the atmosphere as a political landscape has profound implications for the advancement of urban governance and environmental justice, as it acknowledges the historical, demographic, and governance inequalities that have shaped current emission levels. Firstly, it recognises that the distribution of air pollution often follows patterns of historical and social inequities (Asher Ghertner, 2021; Mostafanezhad and Dressler, 2021). Systematically, certain demographics have been found to face a disproportionate burden of poor air quality and related health risks (Brazil, 2022; Demetillo et al., 2021; Stewart et al., 2020). In addition, urban governance and planning have the potential to impact air quality and emissions. Thus, the allocation of resources, the design of public spaces, and the distribution of green infrastructure reflect political priorities and power relations within urban governance (Nieuwenhuis, 2018). Polices such as low emission zones, superblocks, or green corridors exemplify the political nature of addressing air pollution in cities such as Barcelona (in the region of Catalonia, which is an autonomous community in NE Spain) (Anguelovski et al., 2023; Reche et al., 2022). All of these policies have mobilised environmental groups, community organisations,

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and companies, thus reflecting, once again, the political character of the urban atmosphere.

As the impacts of air pollution become an increasingly greater threat for community wellbeing, disputes arise over responsibility, burden-sharing, and mitigation strategies. Correctly recognising and estimating the unequal distribution of responsibilities over current emission levels can help to, not only identify potential paths forward in emission reductions but also, increase the correct ascription of burdens and responsibilities in future climate and air quality policies (Maestre-Andrés et al., 2019; Manville and Cummins, 2015). Failing to recognise these inequalities forces us to continue putting our faith in flawed one-size-fits-all policies that, not only have proven ineffective in tackling the true source of the emission problem but also, generate resentment over population groups that feel they are treated unfairly (Kallbekken and Sælen, 2011). This dynamic effectively erodes trust in public initiatives and, thus, lowers future acceptability of further climate and air quality policies (Christiansen, 2018; Lim and Moon, 2022; Zografos et al., 2020).

In this context, this article has a twofold objective. On the one hand, we examine how emissions from transportation are entangled with social structures of power. That is, we explore how the intersectional combination of gender, age and, migration background is associated with transport-related NO_x pollution in Barcelona. On the other hand, we aim to gain a nuanced understanding of how identities of privilege and oppression combine and operate to influence daily emissions, by using a mosaic of models that are known to theoretically and methodologically address the framework of intersectionality. Hence, we aim to advance environmental justice studies while demonstrating the efficacity of using quantitative methods to study intersectionality.

The following section reviews how social positions relate to uneven exposure to air pollution from transportation. In section 3, we describe how daily mobility emissions were calculated for a representative sample of Barcelona citizens, and the rationale for using a statistical approach that captures the theoretical framework of intersectionality. We then explore the results in order to understand how intertwined identities of power operate and combine to produce uneven contributions to air pollution. Finally, we discuss the implications of the findings within the framework of environmental justice and provide urban policies to promote advancement in this matter.

2. Literature review

Environmental justice studies have vastly uncovered the unfair exposure to air pollution due to traffic. This inequity builds on the fact that certain social groups, defined by their race, gender, class, migration background, and age, are disproportionately exposed to the environmental burdens of mobility (Horton et al., 2022; Poulhès and Proulhac, 2021; Tonne et al., 2018; Verbeek, 2019; Verbeek and Hincks, 2022). Given this unequal exposure, the health impacts of traffic emissions become a significant public health and equity concern. Air pollution from traffic, and particularly nitrogen oxides (NO_x), pose a problem for community health, as it is associated with asthma, heart disease, a diminishment of mental health, and premature death, among other physical and mental health issues (Hao et al., 2022; Host et al., 2020; Mac Domhnaill et al., 2022; Moreno et al., 2022). Since certain social groups have consistently been found to be more prone to the intake of higher doses of traffic-related pollutants, the unfair distribution of air quality produces and then reproduces social oppression (Collins et al., 2022).

Although women, ethnic minorities, new migrants, as well as younger and older adults, are the social groups that are the most exposed to poor air quality, they are not necessarily the groups which are contributing most significantly to emissions from transportation (Horton et al., 2022; Poulhès and Proulhac, 2021; Tonne et al., 2018; Verbeek, 2019; Verbeek and Hincks, 2022). The mismatch between groups with the highest emission levels and groups that are the most exposed to these emissions, presents a conflict in terms of distributive justice. To date, scholars have argued that differences in traffic emissions might be a result of individual preferences and attitudes, such as environmental concerns; mostly among the youth and women (Bayart et al., 2020; Xu, 2020). In combination with the above, scholars have also found that favouritism for alternative modes that were formed before moving to Europe might shape migrants' modal choices (Barajas, 2021; Mattioli et al., 2020).

Nevertheless, the gap between exposure and emissions has additionally been traced to societal and historical power structures that are supported by racism, misogyny, and ageism (Barnes et al., 2019; Mattioli and Scheiner, 2022). These structures are known to constrain access to resources, including private vehicles. While emissions from transportation largely depend on the travel mode, other variables such as vehicle age, engine type, and distance travelled will also determine the environmental footprint (Poulhès and Proulhac, 2022). However, these variables do not operate independently because, for example, Wadud et al (2022) found that individual emissions from mobility are associated with car ownership which, in turn, is a strong predictor of greater travelled distances. As such, these power dynamics have created inequalities that, as a result, have made of car ownership and its associated emissions a form of privilege (Mattioli et al., 2020).

In light of this, previous research has found that recent migrants, women, young people, and older adults have car-access issues that impact their emission levels. For instance, migrants' lower transport environmental impact can be linked to struggles in accessing the required permits in order to drive, such as governmental restrictions on the process of obtaining a valid driving licence, or constraints to secure car financing and insurance (Allen and Wang, 2020; Barajas, 2021; Mattioli and Scheiner, 2022). Hu et al. (2021) further suggest that, although migrants' income tends to increase over time, owning a private vehicle might still constitute a burden for first generation migrants.

In terms of age, younger generations have experienced a delayed entrance into the job market, lower full-time employment rates, low-wages, and higher car insurance costs, which might explain lower car use and emissions from transportation (Colli, 2020; Mattioli et al., 2023; Tilley and Houston, 2016). Older adults, on the other hand, tend to live on fixed incomes that, in some cases, do not allow them to own or maintain a car (Schouten et al., 2022; Vivoda et al., 2020). Age stereotypes on driving performance, together with concerns regarding an individual's physical ability to drive, might also lead a number of senior citizens to not renew their driving licence, in a phenomenon known as driving cessation (Barrett and Gumber, 2019; Chapman et al., 2016).

In the same vein, processes resulting from misogyny also translate into women having lower automobile ownership levels. This phenomenon has been traced to gendered inequalities regarding access to economic resources and a gendered car culture (Mattioli et al., 2020). This uneven access to private vehicles is exemplified through the wage gender gap, women occupying a higher share of part-time jobs than men, or women spending more time close to the home because of the uneven distribution of care work between heterosexual couples (Maciejewska et al., 2019; Scheiner, 2014; Xu, 2020). Overall, the travel behaviour literature has consistently found that the foremost private transport users, and thus the larger emitters, are usually white middle-age men with no recent migration background (Mattioli and Scheiner, 2022; Poulhès and Proulhac, 2022; Wadud et al., 2022).

Despite the abundance of studies that measure differences in travel-related emissions, most assessments to date have narrowed the analysis to a single system of power, i.e. age, gender, or migration history. This trend overlooks the experiences of social groups that embody multiple axes of oppression. Bauer and Scheim (2019a) warn that such experiences should not be assumed as the sum of isolated social positions. In this vein, the theoretical framework of intersectionality recognises that intertwined power structures manifest as unique shapers of the experiences of joint social positions (Guan et al., 2021). First introduced by Crenshaw (1991), the term has historically conceptualised the dual experience of misogyny and racism, with the aim of advancing social justice. Social scientists from different disciplines have shed light on the ways in which adopting an intersectional approach can enhance our understanding of how intertwined axes of identity operate (Evans, 2019; Ravensbergen et al., 2019; Rodó-de-Zárate and Baylina, 2018). However, this perspective is still largely missing in studies examining the environmental impacts of mobility.

3. Methods

3.1. Study area

The Barcelona Metropolitan Area (AMB is the Catalan acronym) encompasses a population of 3.2 million inhabitants over an area of 1,136 km^2. This region, comprised of 35 municipalities, features a ring that is radiating out from Barcelona city centre, which gathers 50 % of the population within 9 % of the area. The urban morphology of Barcelona is compact and mixed, accompanied by a well-distributed range of amenities and services, and an extensive public transportation network (Reche et al., 2022). The first metropolitan ring constitutes an urban continuum with the city core, and it is characterised by varying levels of population density and urban development (Marquet and Miralles-Guasch, 2018). The Barcelona Metropolitan Area constitutes a great study setting as it is representative of traditional European urban form (Delclòs-Alió et al., 2020). It is also a city with a lot of car-alternatives both in terms of active travel and public transport (Codina et al., 2022; Ferrer-Ortiz et al., 2022). That means that inequalities derived from car use are not caused just from extreme car dependency.

The Barcelona Metropolitan Area has one of the highest air pollution levels in Europe, with annual NO_2 mean levels repeatedly surpassing WHO thresholds in highly populated neighbourhoods (Benavides et al., 2019). The main source of NO_x pollution is road transportation, which is responsible for almost 60 % of all emissions in the study area (Badia et al., 2021). Private vehicles are not used very often for trips within the metropolitan area and travelling by car only accounts for 25 % of trips. However, when travelling between the study area and other municipalities, the use of private vehicles sharply increases up to 77 %. This situation can be characterized as common in European metropolitan areas, where public transportation is generally excellent within centre areas but less effective in the periphery (Miralles-Guasch and Tulla Pujol, 2012). In total, 3.2 million car trips are performed daily in the Barcelona Metropolitan Area, and 1 million of these trips start or end outside of it (IERMB, 2021).

3.2. Data sources

With the aim of estimating NO_x contribution, emission factors were obtained from the 'EMEP/EEA air pollutant emission inventory guidebook 2019′ (European Environment Agency, 2019). This guidebook provides information on the emission rate of each transport mode, based on its engine type and age. This inventory is used as a reference to calculate exhaust emissions from transportation, following the method developed by Lejri et al. (2018) and Poulhès and Proulhac (2022) in their research of traffic pollution in Paris. Since electric vehicles (EVs) do not release exhaust emissions, electric vehicle emissions factors were derived from electricity consumption due to battery charging and power generation (Burchart-Korol et al., 2020; Ntziachristos and Samaras, 2021; Van Mierlo et al., 2017).

The second main data source was the 2021 edition of the Working Day Mobility Survey (see Data statement and IERMB, 2021). The questionnaire was focussed on the daily mobility habits, including commercial travel, of a representative sample of the population in the Barcelona Metropolitan Area (n = 4386). This sample excludes mobility professionals, for whom traveling is a key part of their job. Survey participants are asked to report on all trips taken during one weekday prior to the interview, and the modes of transportation used. If a private vehicle was driven, further information about its engine type and year of purchase was collected. In addition, the survey gathered the sociodemographic and household information of participants. This database has a proven track record in research (Maciejewska et al., 2019; Marquet and Miralles-Guasch, 2018; Montero et al., 2022) and detailed methodological information can be found elsewhere (IERMB, 2021).

3.3. Data processing

This section describes how emission factors were assigned to each trip of the mobility survey. Emission factors were then multiplied by travelled distance. For internal-combustion vehicles, emission factors were selected based on the transport mode (car, motorbike, mopped, light commercial vehicle, or bus), engine type (diesel, petrol, CNG, LPG, or hybrid petrol) and year of purchase. Drivers of private motorised modes were asked to disclose the vehicle characteristics and the number of passengers in the questionnaire, thus emissions were adjusted in relation to the vehicle occupancy for each trip. In contrast, the engine type and age of the specific vehicle used for bus and taxi trips were unknown. In such cases, the survey was complemented with data from local operators, and each trip was randomly assigned an engine type and age based on the respective probabilities of its occurrence in the current fleet (AMB, 2021; TMB, 2021).

For electric vehicles, NO_x emission factors derived from power generation due to battery charging, which were calculated based on the electricity mix in Catalonia (Red Eléctrica, 2021; Trozzi et al., 2019). Noteworthily, pure private EVs were only used by 6 out of the 4386 survey respondents. Local public transport operators using electric vehicles shared their own energy consumption, which was adjusted in relation to vehicle occupancy (FGC, 2020; Renfe, 2021; TMB, 2021; Tram, 2021). Estimates of electric scooters, motorbikes, and cars were extracted from life-cycle assessment (LCA) studies (Burchart-Korol et al., 2020; Felipe-Falgas et al., 2022).

We used self-reported survey parameters which included day of the week, departure time, and transport mode, in order to compute the travelled distance. The open-source 'r5r' R package (Pereira et al., 2021) generated multimodal itineraries by combining street network data from OpenStreetMap (OpenStreetMap, 2023) and public transport information from local transit operators in the General Transit Feed Specification (GTFS) format (see Data Statement). For transit routing, maximum walking time was set to 30 min. This time limit is a necessary requirement in order to create feasible routes with transfer times that do not exceed those reported on the survey. The resulting travelled distances were then multiplied by the emission factors to obtain NO_x emissions of each trip segment. Then, the emissions were aggregated to obtain individual daily emissions. After excluding participants with missing or incomplete trip information (n = 981), the dataset ended up with 3,405 users reporting a total of 12,662 trips.

3.4. Statistical analysis

To analyse intercategorical differences between social groups, we build on Guan et al. (2021) framework of quantitative methods for assessing intersectionality. Therefore, we study daily emissions using three statistical approaches, each one addressing a specific research question. These methods examine how categories within each social position (e.g., women), social positions themselves (e.g. gender) and their combination (e.g. gender and age) creating unique intersectional identities (e.g. middle-aged women), are associated to air pollution emissions from mobility. Apart from the social positions gender (men, women), age (16–29, 30–44, 45–64, >65 years) and migration background (European-born or first-generation migrants), the models control for the urban setting by including whether respondents lived in the City of Barcelona or the rest of the Barcelona Metropolitan Area. Regarding migration background, it is worth noting that the term 'foreign-born' is used throughout the text to refer to people born in a place other than Europe, not just outside the study context.

Firstly, we opt for prediction-based methods, in order to answer which social positions (gender, age, or migration background) are most predictive of daily emissions. To do so, we develop a classification and regression tree (CART) using the 'rpart' R package algorithm (Therneau et al., 2022). To limit overfitting the regression tree, we pruned it by choosing the lowest complexity parameter (0.001).

Secondly, to examine daily emission levels across intersectional strata, a multilevel analysis of individual heterogeneity and discriminatory accuracy (MAIHDA) was built using the 'lme4' routine in R (Bates et al., 2015). In this analysis, individuals are nested within social strata, which represent the highest level of the random intercept hierarchical linear model (HLM). Each social stratum constitutes a unique combination of social identities (e.g., European-born young woman). We first developed a null model (Model 1a) which includes no fixed effects. To adjust for the 'additive' social identities, main effect predictors such as gender, age, and migration history are included in Model1b as fixed effects (Evans et al., 2018). Model 1c builds on Model 1b by adding control variables to explore to which degree inequalities attributable to interaction effects can be explained by the urban setting. The objective of this method is to assess the extent to which individual-level characteristics and contextual factors contribute to the variance in emissions, while also estimating the model's predictive performance (Lizotte et al., 2020). To quantify the proportion of the total variance of emissions from transportation that is attributed to differences between strata, we calculated the Variance Partition Coefficient (VPC) (see Alvarez et al., 2022). Additionally, the Proportional Change in Variance (PCV) is provided, which estimates what proportion of the total between-stratum variance from the null model is accounted for by the additive main effects. Finally, a linear regression with categorised intersectional positions was used to evaluate whether, compared to the reference group (45–64-year-old European-born men), other groups experienced different daily emissions. Due to the small sample size of people with a recent migration background who are older than 65 years (n = 12 men and n = 27 women), we decided to not include this group in the linear regression with categorised intersectional positions as it would likely skew the results (Alvarez and Evans, 2021).

Other widely adopted approaches, such as single-level regression models with fixed interaction parameters, were discarded echoing Alvarez and Evans (2021) and Evans et al. (2020) concerns on the suitability of these modes for theoretically and methodologically investigating intersectionality. Using the same argument, decomposition of inequality measures were also excluded (Jackson and VanderWeele, 2019). Similarly, methods to estimate the mediation of intersectional effects were discarded because structural assumptions were not met (Bauer and Scheim, 2019b).

4. Results

4.1. Distribution of emissions

Descriptive analysis is used as a preliminary identification of the effect of intersectional positions on daily emissions. To compare the distribution of population and emissions in our sample, we grouped individuals with the same gender, age, and migration history (Fig. 1). By doing so, we can observe whether emission levels are proportionate to the size of the population group or, on the contrary, whether specific population groups concentrate larger than expected emission levels. The results clearly indicate that daily emissions are not uniformly distributed across strata. The population pyramid, which contains the percentage of the population of each stratum, reveals that middle-aged men, whether they were born in Europe or not, contribute to emissions at a rate that exceeds, and even doubles, their proportional representation in the population. Conversely, younger and older adults, and particularly women, contribute less to air pollution than one might expect. Notably, foreign-born women in nearly every age group emit less than their proportionate share.

4.2. Intersectional social positions and predicted emissions

Prediction methods were used to identify which combination of social positions (gender, age, or migration background) best explain the outcome, while controlling for the urban setting. The regression tree indicates that age is the most predictive variable of daily emissions, followed by gender and place of residence (Fig. 2). While, on average, individuals in the sample emitted 2.15 μg NO_x/day, people older than 65 years emitted 0.86 μg NO_x/day. The tree predicts that the group with a higher environmental contribution consists of middle-aged (30–64 years of age) men who are dwelling in the first metropolitan ring, with a predicted emission between 3.88 and 5.87 μg NO_x/day. Older adults and women, constitute the social groups that are predicted to emit less. Among these social positions, the outcome seems to be similar across people with distinct migration backgrounds.

Secondly, MAIHDA tests whether including interactions between social positions upgrades the model's discriminatory accuracy. In this set of models, individuals (level 1) are clustered within social strata (level 2), which is defined by the unique combination of intersectional identities (e.g., foreign-born young men). The VPC of the null model (Model 1a) is 2.43 %, pointing to both notable emission inequities between strata and substantial overlap in the daily emission distributions of strata (Table 1). In contrast to Model 1a, Model 1b controls for the additive aspects of social positions as it includes main effects predictors, such as gender, as fixed effects. The model shows how the social positions gender and age significantly influence daily emissions from transportation. Comparing the VPC between both models, we see that this measurement dropped to 0.53 %, showing inequalities between strata are not solely explained by additive effects. This is confirmed by the PCV of 78 % between both models, which suggests that 22 % of the between stratum variance may be attributed to interaction effects. With that, this finding seems to confirm that daily emissions at each intersectional identity are different from the simple addition of social positions. The addition of the urban setting controls (Model 1c) maintained the VPC at 0.53 %. This reveals that despite controlling for the urban environment, considerable inequalities and residual interaction effects remained unexplained between intersectional social positions. This last model was used to predict the daily emissions of each stratum (Fig. 3). The group with the highest predicted emission levels is middle-aged men regardless of their migration background and followed by young men. In contrast, the social position with the least impact in air quality is older adults, particularly first-generation migrant women.

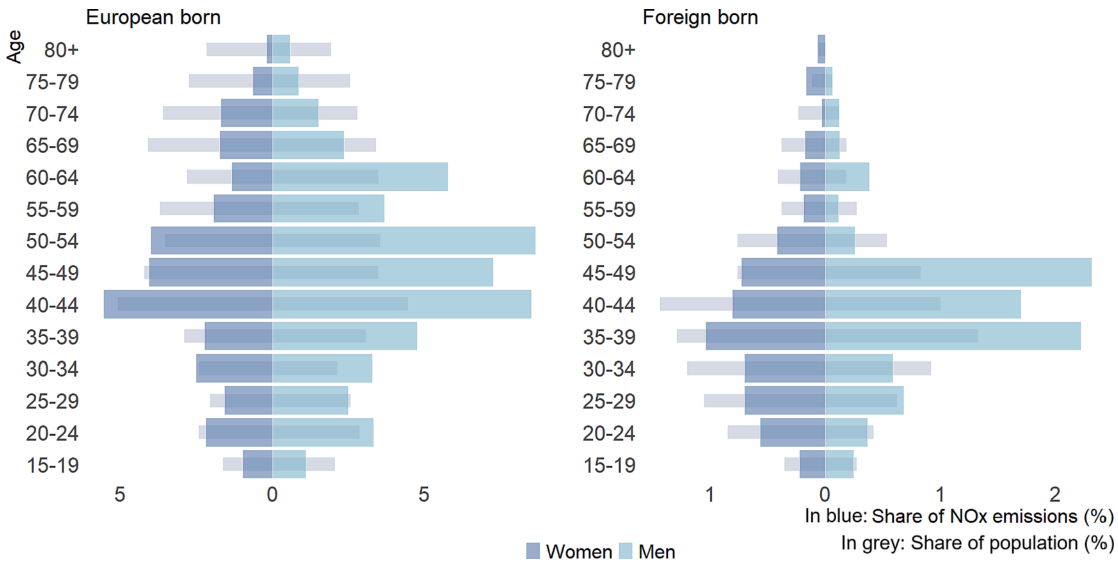

Fig. 1. Share of population and emissions by gender, age, and migration history.

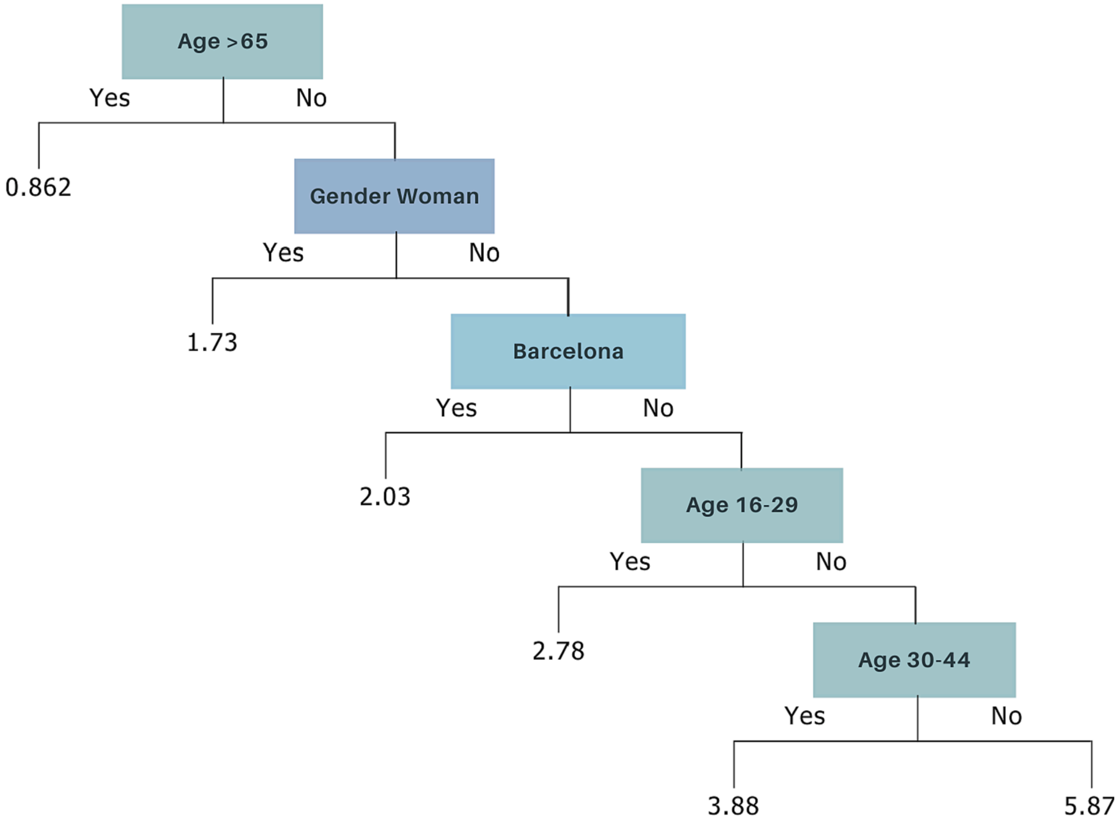

Fig. 2. Predicted individual daily NO_x emissions (µg) from transportation.

Table 1
Daily NO_x emissions from transportation according to sociodemographic attributes.

		Model 1a Without main effects		Model 1b With main effects		Model 1c With main effects and control variables	
Fixed effects		Coeff	CI [95 %]	Coeff	CI [95 %]	Coeff	CI [95 %]
	Intercept	2.11	[1.5–2.7]	3.50	[2.9–4.1]	2.88	[2.2–3.5]
Gender	Man	–	–	=ref		=ref	
	Woman	–	–	−1.26*	[-1.8- −0.7]	−1.25*	[-1.8- −0.7]
Age	16–29	–	–	−0.96*	[-1.8- −0.2]	−0.96*	[-1.8- −0.2]
	30–44	–	–	−0.13	[-0.9–0.6]	−0.15	[-0.9–0.6]
	45–64	–	–	=ref		=ref	
	> 65	–	–	−1.83*	[-2.7- −1.1]	−1.79*	[-2.6- −1]
Migration history	European born	–	–	=ref		=ref	
	Foreign born	–	–	−0.26	[-1.0–0.4]	−0.18	[-0.9–0.5]
Place of residence	Barcelona	–	–	–	–	=ref	
	Rest of the Barcelona Metropolitan Area	–	–	–	–	−1.15*	[-1.6- −0.7]
Random effects							
Strata (σ^2_{u0})		0.93	[0.0–0.6]	0.20	[0–0.6]	0.20	[0–0.6]
Individual (σ^2_{e0})		37.40	[5.9–6.2]	37.39	[6–6.3]	37.08	[5.9–6.2]
Summary statistics							
VPC (%)		2.43		0.53		0.53	
PCV (%)		=ref		78.02		78.32	

*Significant p-values (<0.05) in the analysis of variance.
VPC = Variance Partition Coefficient.
PCV = Proportional Change in Variance.

Finally, to compare how social groups, that are defined by their unique intersectional identity, emit in comparison to the reference group, we built a regression with categorised intersectional positions. The group with the highest mean levels of daily emissions, i.e. 45–64-year-old European-born men, was selected as the reference group. All groups present a significantly lower NO_x contribution

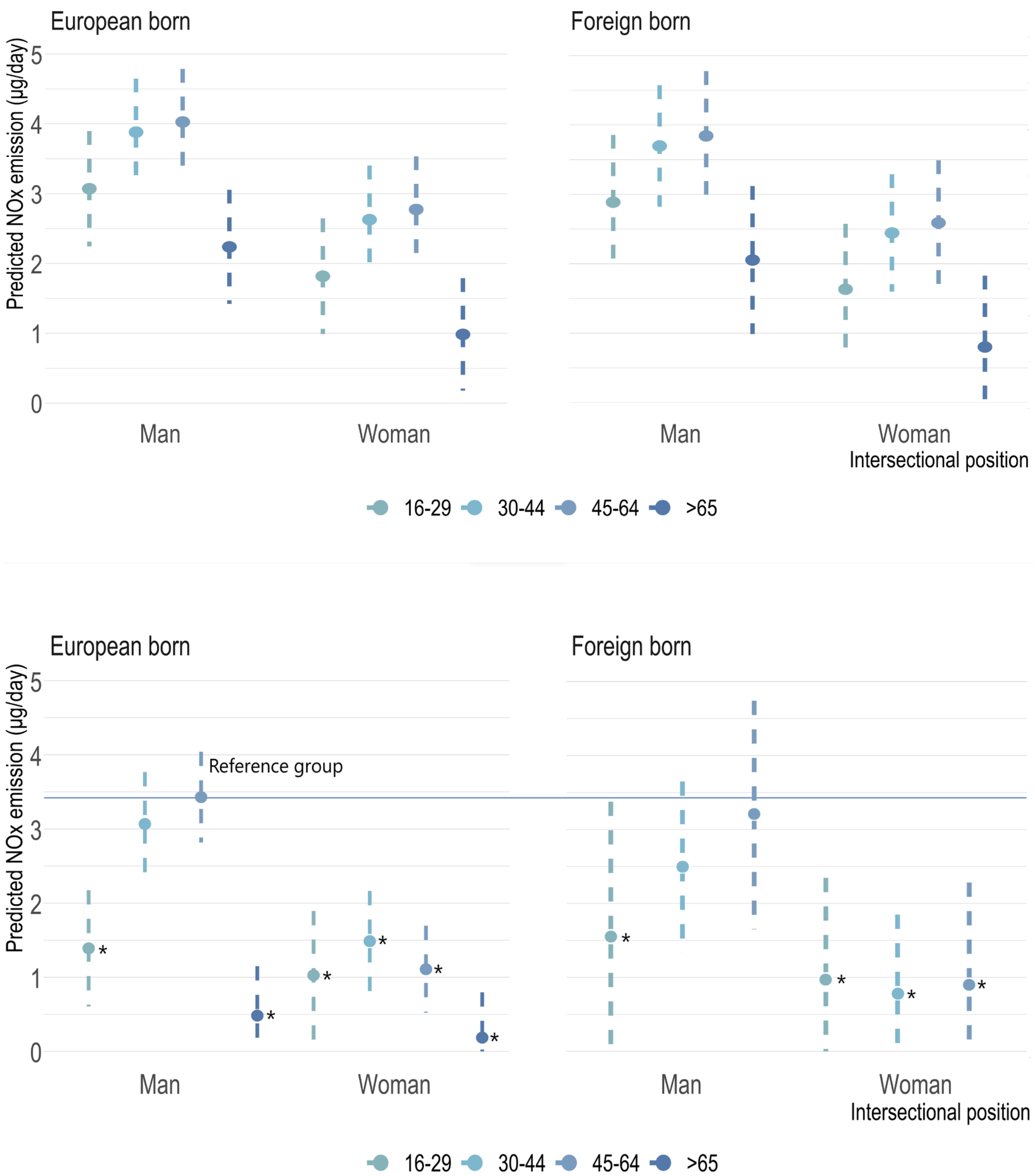

Fig. 3. Predicted NO_x emissions according to the MAIHDA model (top) and to the regression with categorised intersectional positions (bottom). * Significant p-values (<0.05) in the analysis of variance (type II Wald chi-square tests).

than the reference group, except for European- and foreign-born middle-aged men (Fig. 3). Older adults, particularly women, and foreign-born women, regardless of their age, are the social groups with the lowest air pollution footprint because of their mobility habits. Younger adults, notably foreign-born women, also conduct trips with an environmental burden that is inferior to that of middle-aged men.

5. Discussion

5.1. Environmental justice

Emissions from transportation are unevenly distributed among social groups that are defined by intersectional identities. The interaction of age and gender seems to be the best predictor of the individual level of emissions. The models show that younger and older European-born adults have mobility habits that result in lower emissions. This finding is in line with works in the literature that have examined transport emissions of different age groups (Mattioli et al., 2023; Wadud et al., 2022). Nevertheless, age seems to have an even greater effect in the specific case of European-born women. That is, younger and older women are the social groups with the lowest contribution to air pollution among European-born individuals. Previous studies that investigated the effect of either age or gender on mobility emissions also concluded that women, the youth, and older adults are those groups with the lowest environmental footprints (Mattioli and Scheiner, 2022; Poulhès and Proulhac, 2022). But those studies did not account for the specificities of Mediterranean cities, as they were carried out in the UK and Paris (France).

On the other hand, our results support the fact that the mobility habits of middle-aged European-born men are the most NO_x intensive. This finding is consistent with that of Wadud et al. (2022), who suggested that men and the middle-aged perform longer-distance trips with private motorised vehicles that result in higher emission levels. These differences should not be viewed as the result of different preferences over transportation options, as power structures such as racism, sexism, or ageism are known to create socioeconomic inequalities that hinder access to automobiles (Barajas, 2021; Colli, 2020; Vivoda et al., 2020; Xu, 2020). The combination of easier access to the car, intra-household travel decisions and spatial allocation of tasks and trips, contribute to explaining these differences. In this light, the stratum of European-born middle-aged men has unconstrained access to car ownership, which can leverage environmental externalities (Mattioli et al., 2020).

In the Barcelona context, migration background seems to be the least accurate social position with which to predict daily emissions from transportation by itself. However, we found that women with a recent migration background were those individuals with the lowest emission levels. This finding sheds light on the unique experience of women that migrated, which might have been overlooked in the previous literature that analysed traffic emissions due to either gender or migration background (Mattioli et al., 2023; Mattioli and Scheiner, 2022). Nonetheless, studies on the travel mode choice of migrant women also concluded that these women are less prone to commute by car than men (Preston et al., 2022, 2023).

The fact that men have similar emission levels regardless of where they were born, might support that 'transport assimilation' processes are also gendered (Hu et al., 2021; Welsch et al., 2018). Thus, travel patterns of migrant men mirror the patterns of the local population, whereas the modal choice of migrant women might rely on transit and active travel in a higher share (Preston et al., 2022). This is also in accordance with the phenomenon of 'switched intersectionality', in which explanatory variables are only manifested among certain intersecting social positions (Jackson and VanderWeele, 2019). In this case, the effect of migration status on decreasing emissions from transportation appears to apply mostly to women, while men have similar emission levels, regardless of their migration background.

Overall, our results support the fact that emissions from transportation are skewed towards one social group, that is defined by their axes of privilege. This imbalance is aggravated by the fact that the literature has recognised that middle-aged European-born men are not the most exposed to urban air pollution (Horton et al., 2022; Tonne et al., 2018; Verbeek, 2019; Verbeek and Hincks, 2022), nor to its detrimental health effects (Host et al., 2020; Moreno et al., 2022). In the face of environmental justice, there appears to be an imbalance in the power relations between those individuals who use most of the resources for transportation, and those individuals who experience the burdens of that usage. This difference has also been noted by Barnes et al. (2019) in the UK and Poulhès and Proulhac (2022) in France, but has never been observed in Spain, nor in the context of a compact Mediterranean city, such as Barcelona. To advance in environmental justice, there is an opportunity for middle-aged European-born men to reduce emissions by mirroring transport practices of other social groups with environmentally friendlier mobility habits. This is a key process that should be applied in order to decouple equality from emissions (Mattioli et al., 2020). Apart from advancing in equity, decreasing air pollution goes hand in hand with community health benefits, which include a diminishment in asthma cases and premature deaths (Badia et al., 2021; Pierangeli et al., 2020; Poulhès and Proulhac, 2021), and also in distressed mental health situations (Hao et al., 2022; Mac Domhnaill et al., 2022). Improvement of air quality conditions can ameliorate the wellbeing of social groups that are disproportionately exposed to traffic-related emissions.

Understanding the unequal contributions to emissions is a key part of being able to create fair and equitable air pollution-reduction policies. Previous studies have repeatedly found that issues such as a correct ascription of responsibilities, as well as perceived fairness in the allocation of societal costs, are key issues for guiding people towards accepting climate-related policies and regulations (Jakovcevic and Steg, 2013). By changing priorities and the allocation of political attention, climate and air quality policies tend to benefit some population groups, while forcing others to adapt to new conditions in the transportation system or the built environment (Kyriakidis et al., 2023). Designing policies that impact all sectors of society, on equal terms, would, in the face of our results and the results of other studies by different researchers, reproduce a kind of systemic environmental injustice (Lamb et al., 2020). Thus, our findings can help in designing future air quality and climate-oriented interventions in the transportation system, while guaranteeing a correct ascription of responsibilities and avoiding burdening vulnerable population groups with additional costs.

5.2. Intersectionality

Environmental hazards from mobility are significantly explained by the unique combination of social positions. Given the challenges in observing intersectionality issues using quantitative and survey data, we adopted a number of methods based on Guan et al. (2021), in order to understand how each of these positions intersect with one another, so as to result in different mobility habits. This is a significant advancement from traditional studies that have used stratified data by gender or age to observe single-issue inequalities.

To that end, MAIHDA, CART and the linear regressions with categorised intersectional positions set the foundations for acknowledging that social positions operate in an intertwined way and revealed the uneven influence of each in predicting emissions. However, the accuracy of each model differs according to sample size. MAIHDA approach is the most suitable for both small and large simple sizes while the linear regression with categorised intersectional positions is not recommended for small sample sizes (Mahendran et al., 2022). It should be noted that the latter method assumes that the effects of all social positions are similar (Guan et al., 2021). Mahendran et al., 2022 also revealed that CART has been reported to provide the least accurate estimates across sample sizes.

The combined outcome of these methods confirms that intersectional experiences cannot be described as the sum of axes of identity, but rather that they operate in complex ways (Crenshaw, 1991). This phenomenon is evident in the distinct influence of age and gender over emissions among groups with different migration backgrounds, as seen in Fig. 1 and Fig. 3. Following the guidelines of Bauer and Scheim (2019b) and Evans (2019), this study has set out to advance environmental justice, by theoretically framing intersectional positions around power structures. Additionally, our methodological design allowed for the influence of social positions to vary in magnitude and direction at different intersections, with the aim of highlighting potential inequalities that are the result of mobility practices, and discussing the causal processes. Future research should consider the complex ways in which societal structures of power operate and intertwine to capture the experience of those groups that embody multiple axes of oppression to advance in environmental justice.

6. Conclusions

This study has analysed the environmental impacts of the transportation habits of different social groups, under the theoretical framework of intersectionality. The analysed axes are structured around the power dynamics that interplay with gender, age, and migration background. By combining these, we found that intersectional social positions have a deep influence in daily mobility habits, which in turn result in uneven emission levels. Our models indicate that citizens who embody identities of privilege, i.e. middle-aged European-born men, are those with the highest environmental footprint, that is derived from their distinct transportation habits. This analysis expands our knowledge of travel-related emissions, by including all forms of mobility and daily travel and, thus, includes public transport, micromobility modes, and electric vehicles in the estimation of emissions (Barnes et al., 2019; Poulhès and Proulhac, 2022). We also used a mosaic of methods to advance the quantitative intersectionality research, and to discuss the environmental implications of power structures in the discipline of mobility (Guan et al., 2021). To the best of knowledge, our study is among the first to go further in the assessment of individual elements of oppression and demonstrates an ability to estimate the combined effect of social positions on everyday mobility habits and their emission footprints. In doing so, we are contributing to a more accurate understanding of the links between travel behaviour and environmental injustice. At the same time, we are also able to compare the distinct influences that each axis of oppression exerts over travel, and to inform future public policies that are interested in tackling climate change and air quality, while guaranteeing social equity and fairness.

There are certain limitations in this study. Although we use a survey that includes a representative sample of the population of the Barcelona Metropolitan Area, the small sampling size of older adults who were born in a continent other than Europe, did not allow the inclusion of this stratum in part of the analysis. Ethnicity and class of participants were not available in our dataset, and their study would contribute in a valuable way to the knowledge in intersectionality and mobility. In the same line, this analysis would have benefitted from data gathering that would have offered more than two options with which to reflect the gender identity of the population. Further efforts should also be made to examine the balance between emissions and exposure from transportation by adopting an intersectional approach. This paper has explored individual emissions from transportation, but future research should expand how emissions distribute within household members. This approach would shed light on whether the gendered organisation of productive and reproductive work within heterosexual couples translates into distinct emission levels compared to other household units. Overall, this paper is set to advance environmental justice by testing how intersectional social positions influence the environmental outcomes of mobility.

7. Data statement

Emission factors, with which to calculate NO_x emissions, are openly available in European Environmental Agency (2019) Emission Factor Database, EMEP/EEA air pollutant emission inventory guidebook 2019 http://efdb.apps.eea.europa.eu/?source=%7B%22query%22%3A%7B%22match_all%22%3A%7B%7D%7D%2C%22display_type%22%3A%22tabular%22%7D.

Furthermore, transit information in the General Transit Feed Specification (GTFS) format is publicly available for each public transport operator (Table 2).

The mobility survey that supports the findings of this study is available on request from the Barcelona Institute of Regional and Metropolitan Studies (Institut d'Estudis Regionals i Metropolitans de Barcelona). The data are not publicly available due to privacy concerns and/or ethical restrictions.

CRediT authorship contribution statement

Jerònia Cubells: Conceptualization, Data curation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Carme Miralles-Guasch:** Project administration, Resources, Supervision, Conceptualization, Funding acquisition. **Oriol Marquet:** Conceptualization, Funding acquisition, Project administration, Resources, Supervision, Writing – review & editing.

Table 2
Source of GTFS files.

Transit operator	Vehicle	Source of GTFS files
TMB	Subway and inner-city bus	https://developer.tmb.cat/downloads/gtfs.zip
ATM	Tram	https://opendata.tram.cat/GTFS/zip/TBX.zip https://opendata.tram.cat/GTFS/zip/TBS.zip
AMB	Metropolitan bus	https://www.ambmobilitat.cat/OpenData/google_transit.zip
FGC	Railway	https://www.fgc.cat/google/google_transit.zip
Renfe	Train	https://ssl.renfe.com/ftransit/Fichero_CER_FOMENTO/fomento_transit.zip

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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