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"Fast" versus "slow" neighbourhoods? Street speed limits and urban equity

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Abstract

Lowering speed limits is increasingly acknowledged as a key measure to foster resilient streets, improve urban liveability and reduce the environmental impacts of motorised traffic. However, little research has sought to assess street speed limits through the lens of urban equity. Based on OpenStreetMap data, the present paper explores the spatial distribution of street speed limits across different neighbourhoods in Barcelona through various aggregate indicators. My results show that average speed limits vary significantly between neighbourhoods, reflecting the existence of spatial inequities regarding the negative spatial externalities of automobility. Although my analysis shows that neighbourhoods with higher speed limits tend to have higher incomes and motorisation rates, it also draws attention to outlier neighbourhoods which combine high traffic speeds and low motorisation rates. From a distributive justice perspective, I argue that these outlier neighbourhoods should constitute a priority for traffic calming and speed reduction strategies. Finally, I suggest that the proposed speed limit indicators could easily be replicated in other in other cities, thereby enabling cross-city comparisons and providing a useful tool for research, policy and advocacy.

1. Introduction

"Tell me how fast you go and I'll tell you who you are" (Illich 1974, p. 34)

In recent years, proposals to implement city-wide traffic speed limits – typically 30 km/h or 20 mph – have gained traction in local policy agendas, and are increasingly seen as a simple but effective strategy to improve urban equity and liveability, indirectly contributing to broader climate mitigation and resilience goals (Yannis and Michelaraki 2024). Lowering traffic speeds has been shown to deliver a variety of benefits such as reducing traffic fatalities (Elvik 2001; Cairns et al. 2015; Bornioli et al. 2020) and carbon emissions (Nitzsche and Tscharaktschiew 2013), encouraging active travel (Jacobsen, Racioppi, and Rutter 2009), and improving traffic flows (Madireddy et al. 2011). Since the spatial footprint of road infrastructure increases dramatically at higher vehicle speeds (Nello-Deakin 2019), slower speeds can also free up space for other uses such as public space or climate-adaptive green infrastructure. By diminishing the "radical monopoly" of motorised traffic on urban streets, lowering speed limits may contribute to increase equity between transport modes and social groups (Illich 1974). Likewise, the introduction of city- or neighbourhood-wide speed limits may contribute to a more spatially equitable distribution of traffic externalities, by reducing differences in traffic speeds between streets or areas. The introduction of "slow zones" with a 30 km/h speed limit has also been shown to boost levels of outdoor human activity, which in turn may foster social cohesion and urban vitality (Salazar-Miranda et al. 2022).

For all these reasons, lowering urban street speed limits can play an important part in fostering more resilient streets (and neighbourhoods), both by directly contributing to climate mitigation, and by indirectly contributing to enhance social interaction and neighbourhood cohesion. As argued by Fields and Renne (2021), streets have multiple purposes which include not only transportation, but in practice many streets "privilege the speed of vehicles moving somewhere else over the needs of residents whose front doors open on to these spaces" (p. xvi).

Despite their implications for socio-spatial equity, few studies have explicitly assessed the spatial distribution of street speed limits from the perspective of urban equity. Indeed, existing research on urban speed limits tends to be rather technical and narrowly focused on their effects on traffic accidents and public health (Kravetz and Noland 2012; Cairns et al. 2015; Davis and Pilkington 2019), rather than framed within broader conceptual debates related to urban equity and transport justice.

Responding to this research gap, the aim of the present article is three-fold. At a *theoretical* level, **I seek to advance the idea that assessing the spatial distribution of street speed limits offers a novel and meaningful measure of urban equity**. At a *methodological* level, meanwhile, **I propose a method of extracting street speed limit information from OpenStreetMap data, and explore various synthetic indicators of speed limit distribution at a neighbourhood level**. At an *empirical* level, finally, **I seek to assess the relationship between street speed limits and selected neighbourhood characteristics, with a particular focus on neighbourhood socioeconomic status**.

On this last point, I am interested in the extent to which the distribution of speed limits is equitable between neighbourhoods. Do differences in average speed limits between neighbourhoods reflect broader socio-spatial inequalities? Put simply: do "fast" (or "slow") neighbourhoods tend to be rich or poor? In this respect, it is possible two envisage to plausible hypotheses. On the one hand, neighbourhoods with higher socio-economic status (SES) may correspond to neighbourhoods with greater levels of car accessibility, and therefore with higher average speed limits. On the other hand, neighbourhoods with higher SES may correspond to more liveable centrally situated historical neighbourhoods with higher traffic calming levels, while neighbourhoods with lower SES may more often be situated in peripheral locations with a greater presence of high-speed traffic infrastructure.

Both these mechanisms may operate at the same time in different neighbourhoods, making it complicated to identify a single tendency.

Critically, I focus on *legal* speed limits rather than actual measured traffic speeds, for which it is difficult to obtain city-wide data. This means that I not directly assessing traffic speeds themselves, but rather the spatial equity of the formal traffic rules and "infrastructural settlements" (Latham and Wood 2015) governing urban traffic speeds. This admittedly limits the scope of my findings, but is nevertheless highly relevant from a policy perspective, particularly in light of potential concerns regarding the uneven socio-spatial distribution of traffic calming measures and active travel infrastructure (e.g. Aldred et al. 2021; Anguelovski et al. 2023).

In the next section, I briefly discuss existing literature on transport infrastructure and urban equity, situating this article in relation to historical developments in the field. This is followed by three conventionally named sections: Methods, Results, and Discussion.

2. The equity of urban transportation infrastructure

Building upon ideas of environmental justice (Anguelovski 2013) and uneven development (Smith 1984), there exists a long tradition of geographical research focusing on the negative externalities of motorised transportation infrastructure. Empirical studies in this area have frequently found that poorer neighbourhoods are exposed to greater negative traffic externalities (e.g. accidents, noise, pollution) than more affluent ones (Davoudi and Brooks 2014; Kravetz and Noland 2012), although the complex web of historical processes responsible for this trend means that this relationship cannot necessarily be considered causal (Feitelson 2002). While transport researchers have equally been interested in the equity impacts of transport infrastructure (Feitelson 2002; Litman 2022), they have traditionally tended to focus primarily on assessing inequities in destination accessibility and travel time (Martens, Golub, and Robinson 2012; Martens 2016; Banister 2018). The past few years, however, have witnessed the emergence of a "justice turn" in transportation research (Verlinghieri and Schwanen 2020; Karner, Bills, and Golub 2023) which has led to a renewed focus on distributive justice issues beyond transport accessibility, linking them with philosophical theories of justice (Pereira, Schwanen, and Banister 2017; Lewis, MacKenzie, and Kaminsky 2021; Rode 2023). In turn, this "justice turn" can be understood as responding to wider calls for a more critical perspective on urban transportation, moving away from the depoliticised paradigm of "sustainable transportation" (Kębłowski, Dobruszkes, and Boussauw 2022).

Drawing upon these trends, a growing number of researchers have turned their attention to the street level and the distribution of road space between different transport modes (e.g. Nello-Deakin 2019; Creutzig et al. 2020; Guzman et al. 2021). As research in this area has shown, the distribution of space between different transport modes in most cities privileges motorised transport at the cost of other modes, thereby contributing to exacerbate socio-spatial inequities. For this reason, measuring the distribution of space between transport modes may offer a useful way of exposing and tackling these inequities (Szell 2018; Nello-Deakin 2019). As a useful complement to measuring the distribution of space between different transport modes, Nello-Deakin (2019, p. 709) suggests that "it might be promising to focus on the distribution of traffic speed as a complementary measure of urban transport fairness". Drawing upon Illich's (1974) reasoning that high-speed transport modes (i.e. motor cars) tend to be "socially destructive" since they monopolise street space at the cost of other users (i.e. pedestrians, cyclists), Nello-Deakin (2019, p. 709) argues that "a priori, a given area is more equitable the lower its street speed limits are". As Kaufmann (2000) points out, travel speeds are related to social status: high-speed transport infrastructure tends to be used by higher status individuals, while the negative externalities of such infrastructure tend to impact less affluent people and neighbourhoods. In most cases, speed potentials (such as street speed limits) tend to enhance preexisting social inequalities rather than diminish them (Kaufmann 2002). An analogous argument is presented by Graham and Marvin in their seminal book *Splintering Urbanism* (2001, p. 11): "The construction of spaces of mobility and flow for some, however, always involves the construction of barriers for others".

In the present paper, I seek to develop this line of thought by measuring and comparing the distribution of street speed limits between different neighbourhoods in Barcelona, reflecting on their implications for broader urban and transport equity. This exercise, I argue, is especially pertinent at a time when cities worldwide are pursuing far-reaching traffic calming and speed reduction measures.

While not going as far as implementing a city-wide speed limit, over the past couple of decades Barcelona has gradually implemented 30 km/h zones in large swathes of the city, currently covering over half of the city's street network. These speed limit reductions have also been accompanied by the steady implementation of pedestrianisation and shared space schemes, which in recent years have gained international prominence as part of the city's "superblock" strategy (Zografos et al. 2020; Mehdipanah et al. 2019). For these reasons, Barcelona is widely acknowledged as an international reference in human-centric street and public space design, making it an excellent case study for the present article. Nevertheless, there also exist important concerns over the potential implications of street transformation and traffic calming measures – and the superblocks strategy in particular – for urban equity (Anguelovski et al. 2023; Nello-Deakin 2024). While lower traffic speeds are a priori beneficial for urban equity, their uneven geographic implementation might exacerbate differences between neighbourhoods and contribute to issues such as "green gentrification" (Oscilowicz et al. 2020). In this respect, the present study also seeks to contribute to the emerging body of literature assessing the spatial and social equity dimensions of traffic calming schemes, such as London's Low Traffic Neighbourhoods (LTNs) (Aldred et al. 2021; Thomas, Furlong, and Aldred 2022).

3. Methods

My analysis relies on publicly available street speed limit data from OpenStreetMap, using the latest data available in May 2024. To analyse and compare the distribution of street speeds limits between neighbourhoods, I extracted, cleaned and summarised speed limit information for all streets in Barcelona using the open software R. To guarantee the reliability of OpenStreetMap speed limit data, I manually checked the resulting data set against a map of speed limits provided by the Municipality of Barcelona. While there were minor differences between both data sets (both in terms of the street network, and the completeness of speed limit data), aggregate results did not vary significantly between both data sources. The municipal data set was arguably slightly more accurate, but OpenStreetMap data was more up-to-date and more complete in its inclusion of pedestrian streets. Accordingly, I considered OpenStreetMap data to be preferable on the grounds of data accessibility, replicability in other geographical contexts, and up-to-dateness.

More specifically, I extracted speed limit information (identified using the "maxspeed" tag) for all OpenStreetMap line objects with the key "highway" (which includes all types of roads and streets), excluding highway tags which generally do not form part of the urban street network such as "footway", "bridleway" and "path" [1]. In the case of streets tagged as *residential* and *pedestrian* where speed limits were not mentioned, I specified speed limits of 30 km/h and 10 km/h respectively in accordance with local traffic laws. For other highway tags, I excluded from the analysis the very small number of objects with no speed limit information available. In Figure 1, I provide a sample of the resulting map displaying street speed limits.

[1] This includes all following tags within the **highway** category: *road*, *motorway*, *motorway_link*, *pedestrian*, *primary*, *primary_link*, *secondary*, *secondary_link*, *tertiary*, *tertiary_link*, *trunk*, *trunk_link*, *service*, *residential*, *living_street*.

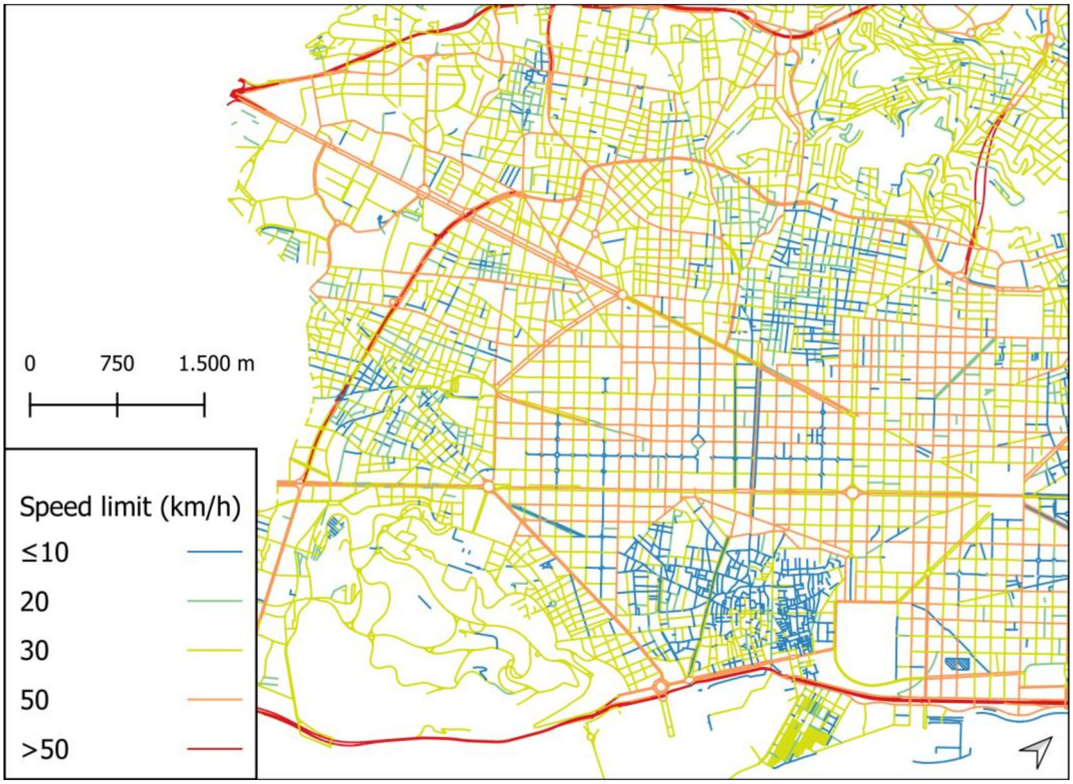


Figure 1: Processed OSM data displaying street speed limits in central Barcelona

To compare the distribution of street speed limits between various neighbourhoods, I spatially intersected the street network layer with a polygon layer depicting official neighbourhood boundaries. A limitation of this method is that it makes no specific exceptions for boundary streets which divide two neighbourhoods. While this means that the assignation of boundary streets risks being somewhat arbitrary, the characteristics of OpenstreetMap road layers significantly mitigates potential distortions in this respect. At least in Barcelona, large avenues and main arterial roads are generally mapped as two individual lines (one for each traffic direction): where these roads coincide with neighbourhood boundaries, these boundaries typically fall between both lines, so that each neighbourhood contains one of the two parallel lines which form the main road. For this reason, I considered that performing a simple spatial intersection provided a good enough approximation for the purposes of the present article.

Subsequently, I calculated four proposed aggregate indicators of street speed limits at a neighbourhood level (Table 1). While it is possible to think of alternative indicators, I argue that these four indicators provide a useful starting point to think about the distribution of urban speed limits, both within and between neighbourhoods. In geographical contexts where different speed limits are prevalent, these indicators could be adapted to reflect local conventions (e.g. 20 mph instead of 30 km/h).

For the first three indicators, I excluded urban highways with speeds above 50 km/h from the calculation. In many cases, these urban highways are segregated from the rest of the street network, with various sections being partially buried or covered. For this reason, I considered that excluding them provided a more accurate representation of neighbourhood speed limits. Since the distribution of high-speed road infrastructure between neighbourhoods is nevertheless an important issue when it comes to assessing the spatial (in)equity of road infrastructure, I also provide a fourth indicator which includes urban highways (*Proportion of urban highways*).

Table 1: Aggregate street speed limit indicators at a neighbourhood level.

Indicator	**Definition**	**Use**
Average neighbourhood speed (km/h)	Mean speed limit for all streets in neighbourhood (weighted by street length)	Provides an intuitive summary indicator of speed limits at a neighbourhood level
Proportion of low-speed streets (%)	% of street network length with a speed limit of 30 km/h or less	Assesses relative presence of traffic-calmed streets
Proportion of urban highways (%)	% of street network length with a speed limit of 50 km/h or more	Assesses relative presence of high-speed road infrastructure
Standard speed deviation	Standard deviation of speed limits relative to neighbourhood mean (weighted by street length)	Indicates the relative spread of speed limits within a given neighbourhood

Regardless of the chosen indicator, it is important to bear in mind that aggregating speed limit data at a neighbourhood level is affected by the modifiable areal unit problem (MAUP), and the zonation effect in particular. Despite this limitation, in Barcelona this problem is somewhat reduced by the fact that most administrative neighbourhoods correspond to historically distinct urban areas with clear boundaries and contrasting urban fabrics. Moreover, neighbourhoods provide an intuitive unit of analysis which lends itself well to policy diagnosis and intervention. In cities where neighbourhood boundaries are more arbitrary, comparing aggregated speed limit information between neighbourhoods may be more problematic.

To assess the extent to which the proposed speed limit indicators (Table 1) are related to key physical and social neighbourhood characteristics, I subsequently explored their relationship with the selected neighbourhood level variables presented in Table 2 through a bivariate correlation analysis. This responds to an exploratory rather than explanatory goal: my aim was not to test specific causal relationships, which are likely to be complex and multidirectional. My choice to focus on these six variables is driven by a pragmatic combination of theoretical reasoning, illustrativeness and data availability. In this respect, *income*, *rental price* and *unemployment rate* should be understood as approximate proxy measures for neighbourhood socio-economic status. Likewise, *motorisation rate* offers the best available proxy for private car modal share, for which no data is available at the neighbourhood level in Barcelona.

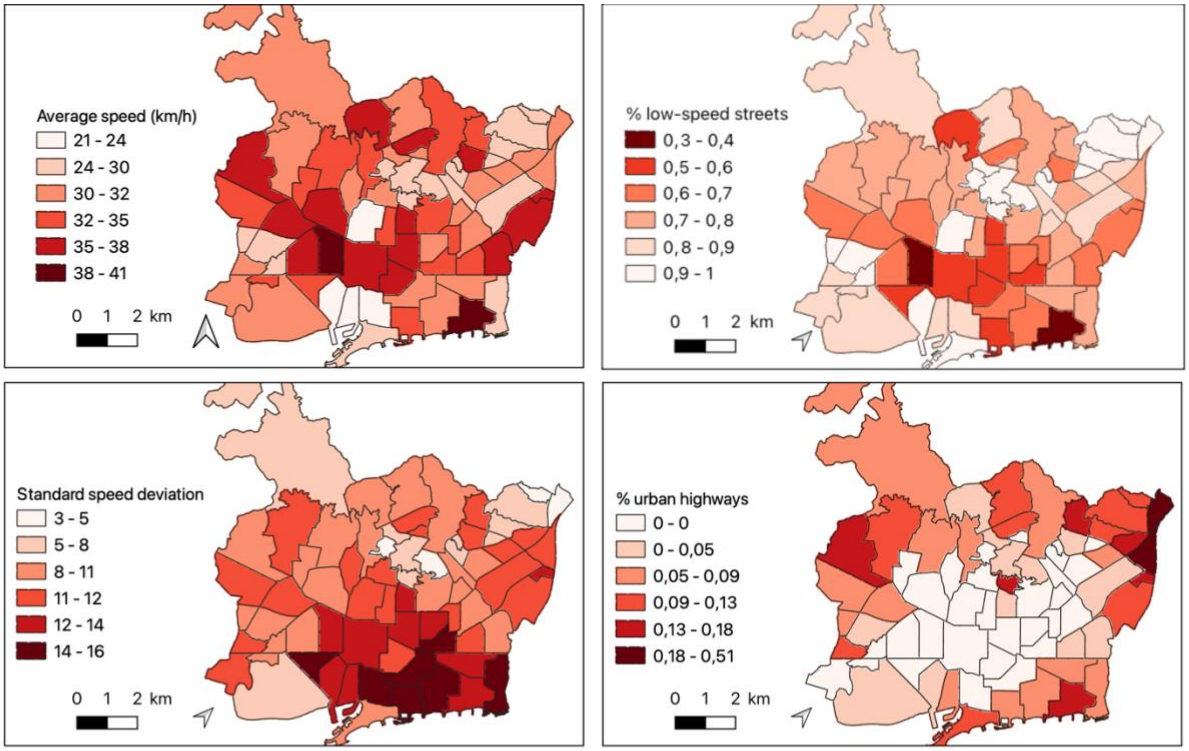
Table 2: Selected neighbourhood level variables (data source: Open Data BCN)

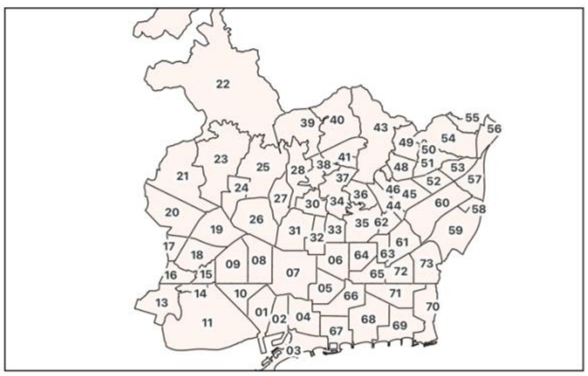
Variable	Definition	Year
Urban density	Inhabitants/km2	2021
Income	Disposable income per person	2019
Rental price	Average residential rental price per m^2	2022
Unemployment rate	% unemployed population (age 16-64)	2023
Motorisation rate	Registered automobiles per inhabitant	2021
Traffic accidents	Total number of traffic accidents per year	2023

4. Results

Distribution of street speed limits by neighbourhood

Figure 2 presents a choropleth map of the four indicators of street speed limits proposed in Table 1. The upper left map shows that average speed limits vary widely between neighbourhoods, from slightly above 20 km/h to 41 km/h. Neighbourhoods with the lowest speed limits correspond to the pre-19th century city centre (01-02-04), and historically independent villages such as Gràcia (31), which were absorbed by the municipality of Barcelona as a result of urban expansion during the 19th century. In both cases, these neighbourhoods correspond to a "pedestrian urban fabric" (Newman, Kosonen, and Kenworthy 2016), characterised by high urban densities and an intricate grid of narrow streets, which limit accessibility and speeds for motorised traffic. While it is more difficult to identify a clear geographical pattern regarding high speeds limits, it is worth highlighting the concentration of multiple neighbourhoods with high average speed limits (05 to 09) in the central Eixample district – a 19th century urban expansion characterised by wide streets and a regular street grid. The presence of large arterial roads also tends to somewhat raise average speed limits for the neighbourhoods they cross, as exemplified most clearly by the case of Avinguda Diagonal (identifiable in Fig. 2 as a straight line dividing multiple neighbourhoods, running diagonally from numbers 20-21 to 05-06).





ID	Neighbourhood
1	el Raval
2	el Barri Gòtic
3	la Barceloneta
4	Sant Pere,Santa Caterina i la Ribera
5	el Fort Pienc
6	la Sagrada Família
7	la Dreta de l'Eixample
8	l'Antiga Esquerra de l'Eixample
9	la Nova Esquerra de l'Eixample
10	Sant Antoni
11	el Poble-sec
13	la Marina de Port
14	la Font de la Guatlla
15	Hostafrancs
16	la Bordeta
17	Sants - Badal
18	Sants
19	les Corts
20	la Maternitat i Sant Ramon
21	Pedralbes
22	Vallvidrera,el Tibidabo i les Planes
23	Sarrià
24	les Tres Torres
25	Sant Gervasi - la Bonanova
26	Sant Gervasi - Galvany
27	el Putxet i el Farró
28	Vallcarca i els Penitents
29	el Coll
30	la Salut
31	la Vila de Gràcia
32	el Camp d'en Grassot i Gràcia Nova
33	el Baix Guinardó
34	Can Baró
35	el Guinardó
36	la Font d'en Fargues
37	el Carmel
38	la Teixonera
39	Sant Genís dels Agudells
40	Montbau
41	la Vall d'Hebron
42	la Clota
43	Horta
44	Vilapicina i la Torre Llobeta
45	Porta
46	el Turó de la Peira
47	Can Peguera
48	la Guineueta
49	Canyelles
50	les Roquetes
51	Verdun
52	la Prosperitat
53	la Trinitat Nova
54	Torre Baró
55	Ciutat Meridiana
56	Vallbona
57	la Trinitat Vella
58	Baró de Viver
59	el Bon Pastor
60	Sant Andreu
61	la Sagrera
62	el Congrés i els Indians
63	Navas
64	el Camp de l'Arpa del Clot
65	el Clot
66	el Parc i la Llacuna del Poblenou
67	la Vila Olímpica del Poblenou
68	el Poblenou
69	Diagonal Mar i el Front Marítim del Poblenou
70	el Besòs i el Maresme
71	Provençals del Poblenou
72	Sant Martí de Provençals
73	la Verneda i la Pau

Figure 2: Street speed limit indicators and neighbourhood names

While the map of low-speed streets (upper right) replicates some of the tendencies described in the first map, it particularly emphasises the lack of high-speed streets in mountainous neighbourhoods evolved out of informal settlements (e.g. 36-38), characterised by an irregular street network and very high gradients. Likewise, it draws attention to the reduced percentage of low-speed streets in the central Eixample district (05 to 09, and 08 in particular).

Neighbourhoods where speed limits present high standard deviations (lower left map), meanwhile, reflect the coexistence of traffic-calmed local streets and main traffic arterials, including various neighbourhoods close to the urban seafront which present relatively mixed urban fabrics. Finally, the map displaying the relative proportion of urban highways (lower right) largely reflects the effect of the peripheral highway ring which surrounds the city, crossing both urban seafront neighbourhoods at the bottom end of the map (03 to 70), and more mountainous neighbourhoods at the top end of the map (21 to 56).

In summary, a visual assessment of the four proposed neighbourhood indicators suggests these speed limit indicators are most clearly affected by the dominant type of urban fabric (historical pedestrian-oriented neighbourhoods vs. subsequent urban expansions), and by the presence of high-speed highway infrastructure. Beyond these patterns, there does not appear to be evidence of a clear geographic trend in the distribution of speed limits at a neighbourhood level. In the following sub-section, I explore the relationship between speed limits and neighbourhood characteristics in more detail.

Relationship with neighbourhood characteristics

In Table 3, I present the correlation coefficients between the proposed speed limit indicators and the six neighbourhood variables listed in the Methods section (Table 2). As can be seen, significance levels vary between different speed limit indicators: while all neighbourhood variables are significantly correlated with one of the three indicators, only unemployment rate is related to all three indicators. By and large, *urban density* does not appear to be related to speed limits, even though less dense neighbourhoods tend to have a higher presence of urban highways. In terms of socio-economic neighbourhood variables, *income* and *unemployment rate* variables suggest that more affluent neighbourhoods tend to present higher average speed limits, while neighbourhoods with a high proportion of slow-speed streets tend to be more deprived. At the same time, however, there exists a significant relationship between neighbourhood unemployment and the presence of urban highways. *Rental prices*, meanwhile, are less clearly related to neighbourhood speed limits. Conforming to theoretical expectations, higher neighbourhood speeds are also associated with a greater number of *traffic accidents*, although it important to be aware that this data is not adjusted for differences in traffic volumes. Finally, neighbourhoods with higher speed limits tend to present a higher *motorisation rate*.

Table 3: Correlation coefficients between street speed limit indicators and neighbourhood variables

	Average speed	% low-speed streets	% urban highways
Income	0.42***	-0.38**	-0.18
Rental price	0.07	-0.29*	-0.11
Traffic accidents	0.34**	-0.49***	-0.18
Motorisation rate	0.48***	-0.29*	0.14
Urban density	-0.16	0.06	-0.46***
Unemployment rate	-0.24	0.25*	0.40***

, **, * indicates significance at the 90%, 95%, and 99% level, respectively*

5. Discussion

The various indicators presented in the results reveal significant differences in the distribution of street speed limits between neighbourhoods in Barcelona. These differences, I argue, reflect the existence of spatial inequities between neighbourhoods regarding the negative spatial externalities of automobility and road infrastructure, of which high speed limits can be thought of as a meaningful proxy.

Based on ideas of distributive justice, I want to suggest that the sufficiency principle might offer a straightforward criterion for municipal authorities seeking to identify and minimise such inequities (Lewis, MacKenzie, and Kaminsky 2021; Pereira, Schwanen, and Banister 2017). This would mean striving to provide a minimum proportion of streets with low speed limits: for instance, aspiring to a minimum 50% threshold of low-speed streets (30 km/h or less) in each neighbourhood. Neighbourhoods which do not meet these minimum requirements – e.g. the Antiga Esquerra de l'Eixample in the case of Barcelona (Fig. 2) – accordingly ought to be considered a priority for traffic calming and speed reduction strategies. As an alternative or complement to such a strategy, the implementation of city-wide speed limits might also offer a useful – if somewhat crude – means of reducing inequities regarding the spatial distribution of speed limits.

My analysis also shows that higher average street speed limits are positively correlated with higher neighbourhood income, even though the results present a significant amount of scatter. This positive association between higher speed limits and income should not be understood as causal, but rather as the outcome of complex interrelations between long-term processes of urban development, socio-spatial segregation and residential selection (Feitelson 2002). These findings arguably run against those of environmental justice literature reporting higher exposure to environmental and traffic externalities in poorer neighbourhoods (Davoudi and Brooks 2014). Likewise, my results seem to disprove suspicions that traffic calming measures may more frequently be implemented in richer neighbourhoods (see Aldred et al. 2021).

Seen from another perspective, however, these results are not surprising, and can be understood as a sign of the frequently noted relationship between speed and wealth: by and large, the rich tend to travel faster than the poor, and use motorised travel modes which more disadvantaged sectors of the population are excluded from (Illich 1974; Kaufmann 2002). These results are a reminder that, despite lots of speculation about the potential of proximity-based planning measures such as the "15-minute city" in contributing to the gentrification of inner-city neighbourhoods (Marquet et al. 2024; Marquet, Fernández Núñez, and Maciejewska 2024), the richest neighbourhoods in Barcelona – as in most cities – in fact tend to be characterised by high levels of car accessibility and traffic infrastructure provision. By contrast, low-speed neighbourhoods predominantly correspond to lower-income inner-city neighbourhoods and mountainous peripheral neighbourhoods, both of which have poor car accessibility. On this point, and despite the difference in geographic setting, our results echo Kravetz and Noland's (2012) finding that speed limits tend to be higher in higher income areas in New Jersey. In future research, it would be interesting to explore whether this association between speed limits and neighbourhood income holds true in other cities, both European – which are likely to be the most comparable in terms of urban and social structure – and worldwide.

At the same time, the positive relationship between speed limits and neighbourhood socioeconomic status is by no means automatic: my results also show that there exists a significant positive correlation between the presence of urban highways (>50 km/h) and neighbourhood unemployment rate. This suggests that high speed limits can not only be a sign of desirable locations with high car accessibility, but also of marginal communities exposed to the negative externalities of highway infrastructure (Graham and Marvin 2001).

Speed limits vs. motorisation rates

My analysis also shows that out of the various neighbourhood-level variables considered in Table 2, *motorisation rate* (which is in turn closely related to socioeconomic status) presents the strongest positive relationship with average speed limits. As noted by Feitelson (2002), it is critical to take local motorisation rates into account when considering the equity implications of traffic infrastructure:

> The distribution of benefits and environmental cost may well vary between societies and regions for similar cases, as a function of motorization rates. The extent to which different population groups can benefit from the different facilities noted here [i.e. road infrastructure] is a function of the availability of cars and the cost of motoring (p. 105).

This relationship between speed limits and motorisation rate, I suggest, offers a valuable perspective on the distributional equity of speed limits between neighbourhoods. Private car modal share would arguably provide an even more relevant variable in this respect, but unfortunately no data is available at a neighbourhood level in Barcelona. If we draw a scatterplot of speed limits versus motorisation rate (Figure 3), we can confirm the broadly positive relationship between both variables: “fast” neighbourhoods tend to have higher motorisation rates, while “slow” neighbourhoods tend to have lower motorisation rates. Albeit in a simplistic sense, I argue that this distribution of speed limits can be thought of as fair or equitable: living in a “fast” neighbourhood provides residents with better motorised vehicle access, but also comes at the cost of higher speed limits, exposing residents to increased negative traffic externalities and a deteriorated public realm. By contrast, residents living in “slow neighbourhoods” benefit from more liveable streets and public spaces, but have to pay the price of reduced car accessibility

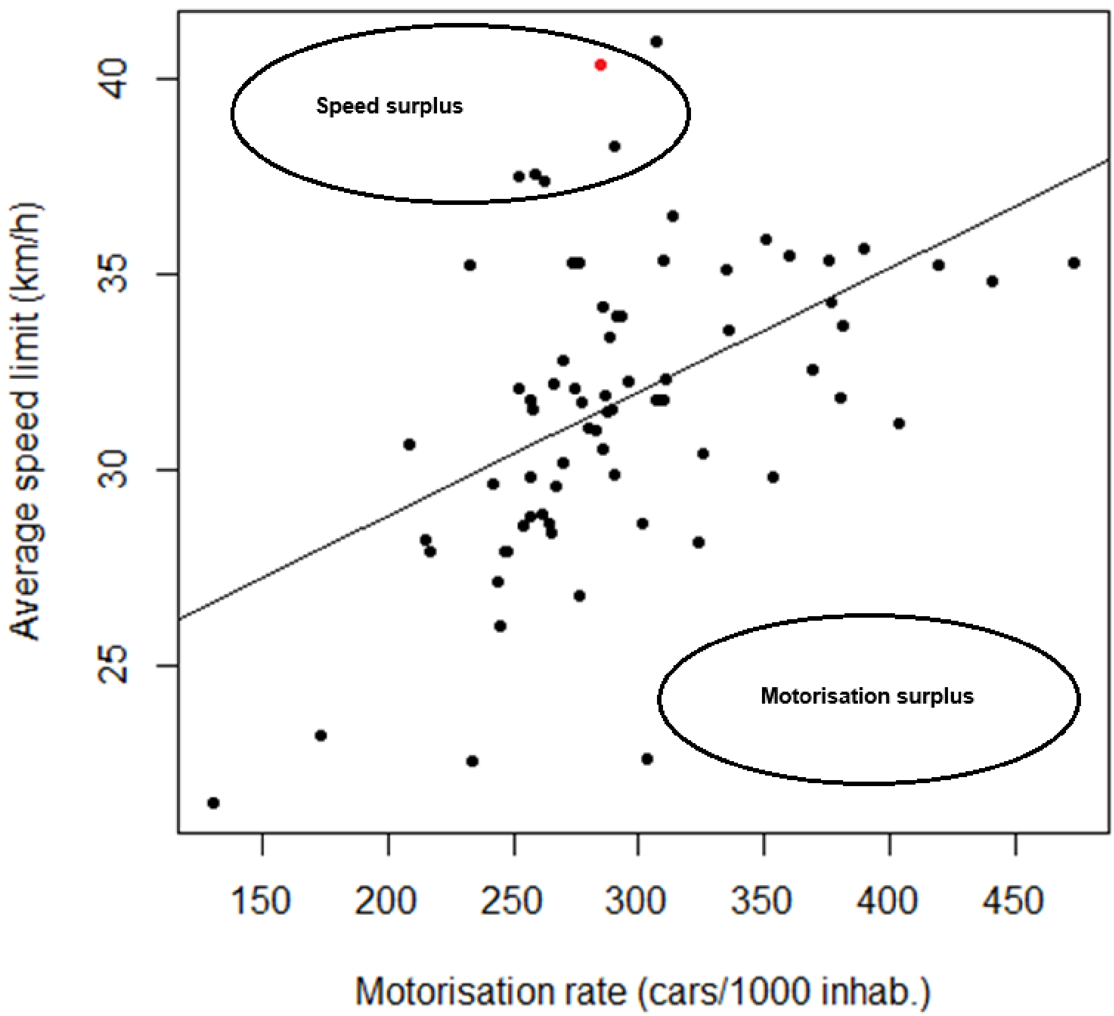


Figure 3: Relationship between motorisation rate and average speed limit

However, Figure 3 also shows that there exists significant scatter in the relationship between motorisation rates and speed limits. Positive outlier neighbourhoods present higher speed limits than expected based on motorisation rates, while the opposite is true for negative outliers.

From this perspective, "fast" neighbourhoods with low motorisation rates (i.e. positive outliers) can be seen as undeservedly bearing the brunt of negative traffic externalities created by drivers living primarily outside the neighbourhood. To illustrate this point, we can consider the case of the strongest positive outlier, highlighted in red in Fig. 3. This corresponds to the *Antiga Esquerra de l'Eixample* neighbourhood, which is characterised by very high urban densities and streets with 3-4 conventional traffic lanes, most of which have a speed limit of 50 km/h. Despite its modest motorisation rate of 285 cars per 1,000 inhabitants, it is the neighbourhood with the second-highest average street speed limits (40.4 km/h) in the whole city. In other words, the streets of the neighbourhood cater predominantly to high-speed car traffic even though its residents are not predominantly car users (as evidenced by its relatively low motorisation rates). These positive outlier neighbourhoods, I argue, can be thought of presenting a "speed surplus" (upper left quadrant in Figure 3), being unfairly exposed to high traffic speeds which are mostly attributable to passing car traffic generated beyond the neighbourhood. From a distributional justice perspective, I argue that such neighbourhoods should be considered as priority sites for implementing traffic calming strategies seeking to reduce local speed limits.

Meanwhile, "slow" neighbourhoods with high motorisation rates might be considered as presenting a "motorisation surplus" (lower right quadrant in Figure 3), unfairly externalising the negative spatial impacts of car use (i.e. high speed limits) to other neighbourhoods while having low speed limits themselves. Following the same distributive justice logic, I suggest that these neighbourhoods might be considered as priority sites for policies to reduce car usage and ownership, rather than for further traffic calming strategies. In the case of Barcelona, however, this category of neighbourhood appears to be relatively absent. While there are various negative outliers, the most prominent of these correspond to historical neighbourhoods dominated by a pedestrian urban fabric, where the motorisation rate is already very low in absolute terms (lower left quadrant in Figure 3). In such neighbourhoods, attempting to reduce motorisation rates even further may prove an unrealistic policy goal.

Limitations and future research directions

To close, I would like to outline various limitations and directions for future study. As previously mentioned, aggregating street speed limits at a neighbourhood level renders results susceptible to the modifiable areal unit problem (MAUP), particularly for small administrative units. Likewise, OpenStreetMap data typically presents minor inaccuracies and omissions (both in terms of the street network and speed limits), which are likely to be more pronounced in regions without a strong contributor base. Thirdly, the speed limit indicators proposed in the present study are relatively crude, and do not take into account the spatial footprint of streets beyond their length. This simplicity makes it easy to replicate these indicators in other contexts, but ignores other relevant aspects such as street network density or surface area. For instance, the high network density of narrow pedestrian streets in historical city centres tends to result in low average speed limits, even though many of these streets may only play a relatively marginal role in the overall activity and mobility dynamics of the neighbourhood. On this point, future research might consider developing more nuanced indicators which include not only length, but also the overall spatial footprint of the street (e.g. street width, surface area or number of lanes). This is particularly relevant in the Spanish context, where the implementation of a new traffic law in 2022 introduced a 30 km/h speed limit for all single-lane streets in urban areas, which might have contributed to reduce differences in speed limits between neighbourhoods. Beyond these methodological limitations, it is worth reiterating that the present study focuses on *legal* speed limits rather than *actual* traffic speeds –, which abundant research shows to generally exceed speed limits (Gargoum, El-Basyouny, and Kim 2016). While this focus on legal speed limits is valuable in assessing spatial inequities regarding the implementation of low-speed zones and traffic calming measures, in the future it would be interesting to complement it with analogous indicators focusing on recorded traffic speeds. Finally, my study only looked at the municipality of Barcelona itself. Particularly regarding the relationship between speed limits and socio-economic neighbourhood characteristics, it would be valuable to extend the analysis to neighbouring municipalities the surrounding metropolitan area, where the presence of high-speed road infrastructure is significantly greater.

Despite these limitations, the simplicity of the proposed indicators means that it would be easy to scale them up in a cost- and time-effective way to enable international cross-city comparisons in future research (assuming OSM data is available). Beyond their use in academic research, aggregate city-level indicators of average speed limits might provide a powerful communicative tool for advocacy and policy initiatives seeking to reduce urban traffic speed limits, enabling the clear identification of leading cities in this domain. This is particularly relevant in light of recent proposals to implement city-wide 30 km/h speed limits in numerous European cities, which have been shown to improve traffic safety and public health, as well as reduce vehicle emissions and fuel consumption (Yannis and Michelaraki 2024). As the recent public debate on the "15-minute city" (Marquet et al. 2024) suggests, it is precisely this type of simple concepts and measures which tend to capture the public imagination and gain traction in policy circles.

Finally, and echoing Nello-Deakin's (2019) call to explore the evolution of road space distribution over time, the availability of OSM historical data means that it should be feasible to explore how average speed limits have changed over time, either in a single or multiple cities. This could provide an insightful perspective into the rate of progress made by various cities in implementing traffic calming strategies, and exploring the effects of changes in regulation such as the introduction of city-wide speed limits. At an intra-city level, this temporal perspective would also allow to see whether speed reduction strategies are prioritising specific neighbourhoods over others. This longitudinal dimension might also help lay the ground to explore potential causal relationships between the evolution of speed limits and relevant mobility indicators, such as car ownership or modal split.

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