Transportation Research Part D 95 (2021) 102860

Contents lists available at ScienceDirect

Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd

Buying a car and the street: Transport justice and urban space distribution

Luis A. Guzman [a,*], Daniel Oviedo [b], Julian Arellana [c], Victor Cantillo-García [a]

[a] Departamento de Ingeniería Civil y Ambiental, Grupo de Sostenibilidad Urbana y Regional, SUR, Universidad de los Andes, Colombia
[b] Transport and Urban Development Planning, Development Planning Unit, University College London, United Kingdom
[c] Department of Civil and Environmental Engineering, Universidad del Norte, Colombia

A R T I C L E I N F O

Keywords:
Street space use
Urban transport
Transport justice
Sustainable transport
Bogotá

A B S T R A C T

In dense cities, the smaller the consumption of land per inhabitant, the more disruptive the use of individual transport as a sustainable transport mode. The impact of private vehicles on transport justice in the spatial dimension is worse there. The unbalanced distribution of street space in dense cities implies considerable challenges for sustainable transport. This paper explores the relationships between mode share, street space distribution, and those spaces' construction costs. Based on justice principles, the paper discusses a fair distribution of street space in Bogotá, where injustices are apparent. We find imbalances in the prioritization of space for specific street users, with an accent on space for private motorization despite a visible change in investment in other spaces for urban mobility in recent years. Findings provide empirical evidence for informing policy and decision-making related to public investment in urban space and its distribution in practice.

1. Introduction

This paper addresses urban space distribution in a dense and congested urban environment in the Global South. Taking Bogotá as a case study, the paper builds on quantitative and spatial analysis to illustrate and unpack the implications of potential injustices in urban space distribution for mobility. The paper contributes to critical debates regarding access and inclusion to opportunities and adequate public spaces, reflected by milestone global agreements such as the new Agenda for Sustainable Development (Caprotti et al., 2017). Such contributions are twofold. On the one hand, we provide empirical evidence on measurable imbalances in the quantity of space of different forms of urban mobility across the socioeconomic structure of Bogotá, an otherwise recognized case of successful urban transport policy.

We adopt a framework of transport justice to transport planning and investment, questioning approaches for distributing economic resources, and reinvesting the tax base associated with urban mobility. Our working definition of transport justice builds on Gössling's (2016) notion of "transport injustice" as a multi-dimensional construct where space distribution is one of three key dimensions that play a determining role in the fair distribution of accessibility (Martens, 2017). The cost of urban mobility infrastructures is essential in transport justice because transport infrastructure development is a capital-intensive activity. The development of long-term and efficient financing for transport systems is essential for citizens' well-being (Kennedy et al., 2005). So, evidence will be shown that the

* Corresponding author.
E-mail addresses: la.guzman@uniandes.edu.co (L.A. Guzman), d.oviedo.11@ucl.ac.uk (D. Oviedo), jarellana@uninorte.edu.co (J. Arellana), va.cantillo@uniandes.edu.co (V. Cantillo-García).

https://doi.org/10.1016/j.trd.2021.102860

Available online 13 May 2021

expected tax collection from mobility-related rates for the period 2017–2019 from the Bogotá city budget is only a small part of the infrastructure costs necessary to accommodate cars and motorcycles.

Sustainable mobility and transport justice must be fully supported by the state and by society. The fair distribution of urban space is a significant challenge for authorities and urban planners. Structural asymmetries in the use and enjoyment of such space lead to inequalities in the rights and freedoms of who, when, and how to use it (Martens et al., 2012). The inherent asymmetry built mainly during the twentieth century has become more visible, thanks to the mobility paradigm shift (Banister, 2008). Such asymmetries highlight the importance of analyzing the distribution of benefits and costs related to urban transport in the population and determine how urban space is distributed among travelers, deepening or alleviating transport injustices.

This research's primary goal is to highlight street space distribution in a dense city, operationalizing transport justice through a spatial analysis approach. We recognize the structural differences between cities such as Bogotá and cities in the Global North, enriching space distribution-related transport justice discussions. Transport justice, or the fair distribution of street space, is critical for developing a transport system that offers equal access to public space and opportunities. We present a data-driven methodology for street space classification that uses machine learning algorithms. We classified the street space in sidewalks, bike paths, Bus Rapid Transit (BRT) exclusive corridors, and traditional road areas, separated by private vehicles and regular buses. We use Geographic Information Systems (GIS) to create a geographical layer of around 103,000 segments that accurately divides Bogotá's street space, using publicly available information from Bogotá's geodatabases (Medaglia et al., 2020). The paper contributes to understanding the spatial inequalities of private transport at the urban scale. It proposes a novel perspective to local and regional debates on infrastructure and urban space not often approached from a distributional perspective.

2. Urban space distribution as an input of transport justice

Justice theory is a contested debate drawing from philosophy, sociology, and political science (Pereira et al., 2017). Principles of urban justice build from notions such as "the right to the city" proposed by Lefebvre (1996) to spatial justice (Soja, 2010). It reflects a concern about how urban space is used and how decisions about its design are made in line with Fraser's (1998) definition of distributive justice as distributing goods within a city focusing on its socioeconomic rooting. Urban justice also responds to Fainstein's (2014) plead to design cities to enable social justice for all rather than prioritize economic growth. Rawls (1999) -perhaps one of the more influential scholars on justice-, suggested that access to all resources should be distributed equally to all people.

The notion of transport justice builds on the above foundations to interrogate the distributional effects of transport provision and the associated disparities in its impacts across social groups (Jones and Lucas, 2012). Affordability, accessibility, and mobility are recognized as critical transport justice dimensions (Martens and Hurvitz, 2011). However, their interdependence may often lead to conflicting outcomes (Manaugh et al., 2015). The emerging interest in transport justice has led to many approaches to define and measure it, from the capability approach (Beyazit, 2011) and transport-related exclusion (Lucas, 2012) to a focus on differential exposure to transport-related externalities (Boyce et al., 2016; Samoli et al., 2019) and benefits (Hananel and Berechman, 2016). Such studies address transport as a critical factor in improving urban well-being that simultaneously drives spatiotemporal disparities in access to opportunities (Lucas, 2012).

Martens contributes to the transport justice debate by presenting philosophical discussions and a working definition building on the dimensions above that sets a desirable setup of potential mobility and accessibility as a target of transport justice while recognizing "least advantaged groups" (Martens, 2017). This theory has not been without controversy (Martens, 2020; Vanoutrive and Cooper, 2020, 2019). It has both informed and evolved in parallel to further debates on the notion of mobility justice, which articulates urban mobility with broader concerns about power, politics, and social exclusion (Cook and Butz, 2018).

Transport justice's focus on accessibility distribution and its implications (Dong, 2019) is increasingly relevant in cities with already high population densities that follow an upward trend, such as those in Latin America and Asia (Güneralp et al., 2020). In contexts where transport systems traditionally benefit motor vehicle users and owners, the distribution of available space and facilities for urban mobility places significant burdens on pedestrians, cyclists, and the bulk of society (Mullen et al., 2014). Rapidly growing urban contexts show low average land consumption per capita and low ownership rates of individual motorized vehicles, deepening existing spatial inequalities. An encompassing feature of transport planning in the Global South is the central role of automobility infrastructure, despite the predominance of the non-motorized modes (Uteng and Lucas, 2017). Such predominance of car-centered transport networks gives urban street use in developing cities a conflicting nature, with an intricate coexistence of pedestrians, vehicles, street vendors, and other competing uses of limited spaces that make interventions more difficult (Dimitriou and Gakenheimer, 2012; Vasconcellos, 2014). The emphasis on individual-transport infrastructure provision coupled with the unregulated use of streets often leads to the overuse of road space, aggravating negative externalities (Santos et al., 2010).

The fair distribution of street space can balance transport systems' injustices, such as the suppression of trips not acknowledged by mainstream transport planning (Levy, 2015). A paradigm shift is needed to incorporate the distribution of travel choice and the social design of mobility into transport decision-making and investment (Ernste et al., 2012; Levy, 2013). Recognition of mobility needs and providing adequate and sufficient facilities and spaces without undermining the ability to provide conditions that protect the most vulnerable or compromising future sustainability requires complex trade-offs and balancing of costs, benefits, and priorities (Mullen et al., 2014). The application of justice frameworks to the socioeconomically differentiated availability and access to space can inform fairer and more proportionate urban spaces' distributions while encouraging sustainable transport modes (Jian et al., 2020).

Critically examining urban space distribution fairness puts into question conventional street space allocation principles made to minimize motorized transport modes' total travel time (Zheng and Geroliminis, 2013). By recognizing the high cost that a minority of car users is imposing on the majority in terms of congestion, air pollution, road safety, and use of street space, cities take a first step in democratizing urban space (Karndacharuk et al., 2014). Such a realization has taken longer to gain traction in cities of the Global South. In these contexts, using the existing street space more efficiently could increase fairness according to modal share in terms of space distribution (Gössling, 2016). Measuring the physical characteristics of urban space presents a challenge, particularly in cities of the Global South. The most established strategy for measuring the distribution of road space given to different modal share is using GIS cartography in Amsterdam (Milieudefensie, 2017; Nello-Deakin, 2019), satellite imagery processing in Freiburg (Gössling et al., 2016), or data collected directly from some streets in Berlin (Creutzig et al., 2020). There are also previous analyses but only looked at specific spots in three cities (Copenhagenize, 2014). Few studies measure equality in the distribution of street space. Szell (2018) studied the imbalance between modal share and space distribution in 23 cities worldwide, finding a historic car-centric urban planning.

As seen, few academic works have focused on actual street space distribution regarding transport mode use. Such research has been applied in developed cities (Gössling, 2016; Nello-Deakin, 2019; Szell, 2018). Moreover, research operationalizing distributional perspectives to transport has suggested applying indicators such as Lorenz Curves and Gini indices can make explicit transport-driven inequalities (Delbosc and Currie, 2011a; Guzman et al., 2017b; Jang et al., 2017). To the best of our knowledge, there have been no studies reported using this approach in Global South cities to understand urban space distribution and modal share; this constitutes a research gap that motivates our study.

3. Bogotá: Socioeconomic segregation and mobility patterns

Most of the low-income population in Bogotá lives in zones with few economic opportunities and are located in the urban periphery, far from the leading employment centers (Guzman and Bocarejo, 2017). Moreover, most of these settlements were developed informally (Guzman et al., 2017a). This implies a significant deficit of urban amenities, green areas, public spaces, and transport infrastructure, which is currently maintained in those zones. Moreover, it is in these zones that the highest population densities occur (see Fig. 1a).

In 2018, the city of Bogotá was comprised of 7.42 million people. The 380 km^2 of the city's urban area is divided into 19 urban districts (*localidades* in Spanish). Districts are a spatial division from a geographical, social, and economic perspective of political-administrative division. Accordingly, Bogotá is one of the densest cities globally, and it is the densest in Latin America with around 19,500 inh/km^2. However, the distribution of the population is uneven across the territory, just like the proportion of street space: People from different districts experience unequal conditions in terms of density and availability of space.

As shown in Fig. 1b, there is clear economic segregation between north and south, with the low-income districts located in the south-west and south of the city. Most of the households' income is less than 660 USD/month, whereas the wealthiest areas are in the north: in high-income districts, the average income is above 1000 USD/month. Also, the distribution of cycling and public transport facilities infrastructure suggests a reinforcement in wealthy areas (see Fig. 1c).

This type of development has resulted in inequalities of all kinds: economic, social, and infrastructural. One of the main inequality issues and less studied is the uneven distribution of street space across the urban territory (districts). People from southern and western zones depend on non-motorized and public transport (PT) modes for daily trips and live in high-dense and unbalanced territory. On the other hand, people located in central zones have a much more balanced territory and lower densities (Guzman and Bocarejo, 2017), as is shown in Table 1.

Fig. 2 shows that for trips of up to 2 km, walking is, by far, the most used transport mode in the city. The total number of walking

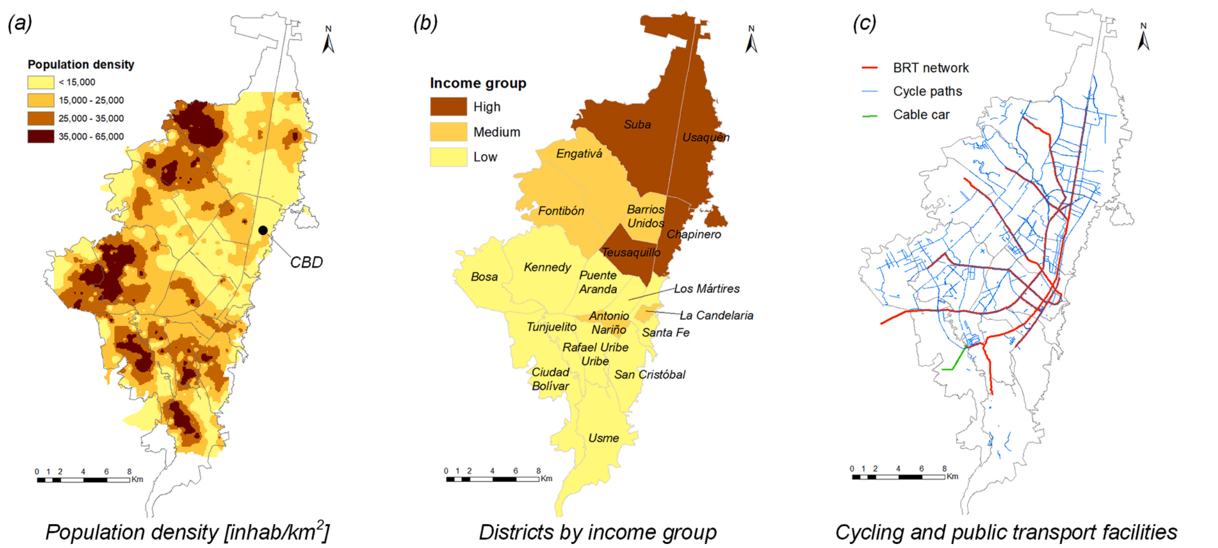


Fig. 1. Bogotá by districts: population density, average income group, and transport facilities, Source: own elaboration from official data 2015/2016.

trips in Bogotá is around 4.6 million per day. Fig. 2 also suggests that most of the *Bogotanos* walk distances of up to 2.5 km, while people who travel long distances (i.e., more than 10 km) prefer using the BRT (Guzman et al., 2020). Also, the car-ownership rate in Bogotá is low: just one of seven inhabitants have a car on average. Nevertheless, this indicator varies according to the income group. There are 0.25 cars/inhab in the high-income group, 0.19 in medium, and 0.09 in the low-income group. This means that people from high-income districts have on average 2.8 more cars per capita than poor.

The modal share in Bogotá is directly related to the street space classified in this paper: bicycle paths, sidewalks, BRT exclusive corridors, and individual motorized vehicles including car, moto, and taxi, which share the same road space with regular buses. These results highlight the importance of having sufficient and quality infrastructure for active and public modes.

Although the socioeconomic distribution and mobility patterns suggest that Bogotá is an unequal and highly segregated city, a more in-depth look at the available street space considering the modal share throughout the city can help assess the fairness of the distribution of public infrastructure. The following sections analyze and discuss the distribution of street space as a tool to improve transportation justice and how to plan and design better urban environments.

4. Methodological approach

We propose a methodology based on the calculation of a set of indicators that aim to evaluate the fairness of the allocation of street space in Bogotá, identifying incentives or advantages for private vehicles in terms of the dedicated public space. The results are then analyzed to determine critical points for city planning and policymaking in light of transport justice. A comparison of total street space consumption (static and dynamic) by different transport modes allows us to analyze the efficiency of space usage by different modes, assuming volumes of travel from a mobility survey and estimating how fair the current situation is in Bogotá.

4.1. Data

We relied on data from two primary sources: the official mobility survey of 2015 Bogotá, from which we calculated daily modal shares, travel times, and trip distances by mode. The second step was the quantification and classification of street space. In this case, we used the complete cross-section of the city's entire transport network from public databases. The GIS-processed geographical databases contained spatial information regarding the area dedicated to each type of infrastructure included in the analysis. The transport facilities include median strip, roadways, BRT exclusive corridors, sidewalks, and cycle paths. To separate the area used by regular bus and private transport (car, moto, and taxi), we used official information of the regular bus subsystem services such as line length, travel time, headways, frequencies, and fleet. Using this we can calculate a proxy of street space used by regular buses.

Finally, we estimated the approximate current cost of each type of facility by the city's official reference unitary prices for the planning and development of infrastructure and public space projects, including public bids (IDU, 2020). According to infrastructure costs concerning the tax collection from car ownership from the 2017–2019 period, this will be analyzed under the justice framework. It is relevant to note that the estimated costs are exclusively related to the pavements, and do not include complementary works such as public services networks, street furniture, or signaling.

4.2. The supply side: Quantifying the street space

Street space by segment classification is based on several components that comprise the entirety of the urban transport network of Bogotá. The street segments are divisions defined by local administration with a unique ID. This ID is shared within the street segments' components: median strip, roads, BRT exclusive corridors, sidewalks, and cycle paths.

From the local geospatial office IDECA[1], we retrieved the layers of street segments in Bogotá, including those of cycling and pedestrian infrastructure. From OpenStreetMap, we retrieved the base polyline of the road network segments from Bogotá. Thus, total street space was calculated using GIS software and software R. We then processed the different layers with these facility types and used a merging process to produce a single-grouped polygon for each street segment. Based on these available layers, the resulting layer corresponds to the whole city's street space composition, with a total of 103,366 grouped features, which includes 115,510 flow mix roads, 167,841 sidewalk features, and 4758 bicycle path features (Medaglia et al., 2020). As described earlier, we divided the city into 19 districts to explore differences in street space distribution within Bogotá.

It is valid to clarify that while the above classification divides the street space into separate modes, in practice, several streets allow mixed traffic (e.g., cars, motorcycles, taxis, and regular buses share mixed-flow roads). In these spaces, buses' area was separated according to the proportion of dynamic street space occupied by each mode. Also, we calculated BRT corridors, pedestrian sidewalks, and cycle paths separately.

4.3. Measuring the use of street space

The second stage of the proposed methodology consists of an aggregated evaluation of the total area available to each facility in the city, compared to the modal share. First, from a static perspective, we introduce an indicator dividing the area into squared meters by

[1] www.ideca.gov.co

Table 1
Socioeconomic characteristics and modal share by district.

District	Income group	Population	Density [inhab/km^2]	Cars/inhab	Modal share [%]				Job/Pop ratio
					Car, moto, taxi	*PT*	*Walk*	*Bicycle*	
Chapinero	H	132,258	19,930	0.42	45.3	21.6	32.6	0.5	3.78
Usaquén	H	467,530	13,620	0.33	39.5	26.8	32.0	1.6	0.56
Teusaquillo	H	147,395	11,600	0.30	39.6	26.4	33.3	0.7	1.14
Suba	H	1,084,103	18,980	0.19	24.4	30.7	41.7	3.2	0.24
Barrios Unidos	M	231,658	22,000	0.22	31.0	26.8	40.6	1.6	0.91
Fontibón	M	342,442	11,420	0.22	21.5	32.2	41.8	4.5	0.68
Antonio Nariño	M	107,631	22,800	0.18	23.5	35.0	40.6	0.9	0.75
La Candelaria	M	23,924	11,800	0.14	4.7	26.5	67.7	1.1	2.09
Engativá	M	836,268	28,700	0.17	13.9	37.8	44.3	4.1	0.35
Santa Fe	L	102,706	16,440	0.11	13.0	28.8	57.6	0.5	1.65
Kennedy	L	1,014,051	29,220	0.12	14.0	31.9	49.4	4.7	0.31
Puente Aranda	L	256,143	15,200	0.15	19.5	31.6	46.3	2.6	1.18
Tunjuelito	L	200,010	28,340	0.12	16.2	34.9	45.2	3.7	0.33
Los Mártires	L	97,037	15,130	0.17	17.7	25.5	54.7	2.0	1.77
San Cristóbal	L	405,761	28,130	0.06	10.5	33.2	55.2	1.1	0.20
Rafael Uribe Uribe	L	374,260	29,930	0.08	10.2	36.0	52.2	1.6	0.25
Bosa	L	577,617	30,630	0.07	6.1	30.5	57.6	5.8	0.10
Ciudad Bolívar	L	632,559	22,600	0.05	6.8	37.3	53.7	2.2	0.12
Usme	L	379,212	15,450	0.05	4.4	33.7	61.1	0.7	0.14

Source: own elaboration with data from 2015 mobility survey.

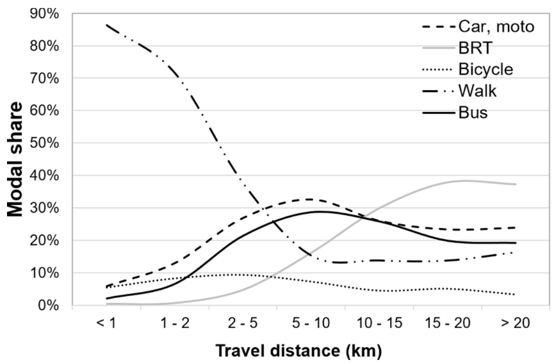


Fig. 2. Distribution of travel distance and modal share, Source: own elaboration with data from 2015 mobility survey.

the corresponding transport mode's total daily trips. The roads' area was separated into the regular bus and other motorized modes (car, motorcycle, and taxi), the sidewalks to walking, etc. This indicator shows the area dedicated to producing one trip in the corresponding mode. Then, the higher it is the indicator, the less efficient the mode is because it uses more space to mobilize people. Parking areas were not estimated because, in Bogotá, parking in the street space is not allowed in theory.

Nevertheless, as vehicles and people move, another indicator is necessary to compare the total space used for different transport modes. Using the concept of time-area occupancy (Bruun and Vuchic, 1995), obtained by the product of the space and the time occupied by a vehicle, it is possible to estimate, simultaneously, the quantity of the required space for movement and also the time for which this space is occupied. Therefore, we propose a second indicator consisting of the ratio of the available time-area for each facility and the space consumption of the trips, which results in the average occupation of the available facility on a typical day. Then, the space requirements for moving transport are a function of speed, as described in Eq. (1).

$$A_i = \frac{\left(\frac{S^*R}{3.6} + L\right)W}{P} {}^*T = \frac{M^*W}{P} {}^*T$$

As this indicator increases, it means that the corresponding users occupy more street space. Here, A_i is the time-area consumed in m^2-min by passenger i; S corresponds to the average speed of the vehicle in kilometers per hour (door-to-door); R refers to the safe reaction time or gap required by the driver expressed in seconds; L is the average vehicle length in meters; W is the average lane width in meters (right-of-way); P stands for the number of passengers or occupancy of the vehicle, while T is the total travel time in minutes. M is the area of the right of way occupied by the vehicle/traveler. The travel speed for each mode of transport was estimated using the average travel time and distance from the Bogotá mobility survey and the average occupancy by vehicle.

Note that it is necessary to multiply the time-area consumption of a single average user in Eq. (1) by the total of trips per mode. This approach provided a proxy for the street space consumption required to mobilize the daily travel demand by mode at different levels of service.

Given buses and private motorized vehicles share mixed roads, an aggregated analysis might lead to wrong conclusions because the demand for regular buses would not be differentiated from individual and private vehicles. We then propose a methodology to estimate the share of the road network is dedicated to buses. First, we estimated the total dynamic area consumed by regular buses from Eq. (1) using all services' official timetables, including line length, travel time, headways, frequencies, and fleet. The car, moto, and taxi's dynamic area were estimated, multiplying the daily trips' time-area consumption, as described before. Then, assuming a one-to-one relation between dynamic and static areas, the share of the roads dedicated to bus is the proportion of dynamic area occupied by the mode from the modes' total consumed in mixed roads.

We also propose a disaggregated approach to analyze the street space distribution and its use at the district level. We estimated the same indicators for each district to examine the differences. Finally, we propose using infrastructure construction costs to estimate the value of urban space per mode. We estimated each facility category's current construction cost by multiplying the area of the infrastructure by the official reference unitary prices. Then we computed the total cost ratio and the daily trips made in each mode, obtaining a proxy value on infrastructure per trip. Finally, we compared the projected value of urban space in transport and the expected tax collection from mobility-related rates in Bogotá budgets for the period 2017–2019 to analyze whether the users fully pay the construction costs made for the private vehicle infrastructure, or whether instead there is some implicit subsidy for every mode. Finally, we calculate the Lorenz curves and the corresponding Gini index of the distribution of street space. From these indicators, we obtain the cumulative share of space by facility type by different population sections.

5. Results and analysis

In 2015, Bogotá produced around 14.8 million trips per day within its limits. Public transport has the highest share (46.6%) of trips, followed by non-motorized (34.5%) and private transport (17.0%). Transport infrastructure (i.e., roads, BRT trunk corridors, sidewalks, and cycle paths) occupies around 21.2% (89.7 km^2) of the urban area. Buses (i.e., feeder lines, regular and inter-municipal buses) have a modal share of 32.8% and share the space with motorized private transport, cars, taxi, and motorcycles (17%). The share of road network used by the regular bus subsystem is approximate 11.7%.

The distribution of street space by category in Bogotá and the daily modal share is shown in Fig. 3a. Mix traffic (i.e., car, taxi, moto, regular bus) and pedestrian areas occupied by far the most street space (97.6%), followed far behind by BRT corridors (1.5%) and bicycle paths (0.9%). Fig. 3b introduces a new indicator: street space and modal share ratio by district income group. This ratio indicates the relationship between the dedicated area and the modal share of a category. A ratio of 1.1 indicates that for the "walk" category there is 10% more dedicated space for the "walk" category than the trips made in this mode. On the contrary, a ratio of 0.1 indicates that in the BRT category, there is much less space dedicated to this mode regarding the trips it moves, being much more efficient in terms of the use of space.

The results in Fig. 3 show the first evidence of injustice. First, there is a clear trend to give more space to less sustainable modes (car, motorcycle). These modes also generate negative externalities that negatively affect more sustainable transport alternatives. Second, in the low-income districts, where a modal share in private modes is lower, more space is dedicated to these modes (relative to the trips). Besides, higher-income districts dedicate proportionally more space to pedestrians. The above results suggest an imbalance in the provision of transport infrastructure across the city, which is in line with the results reported in other Colombian cities (Arellana et al., 2020).

From a dynamic perspective, street space distribution is much more unfair, as is shown in Fig. 4. Here, a numerical example for

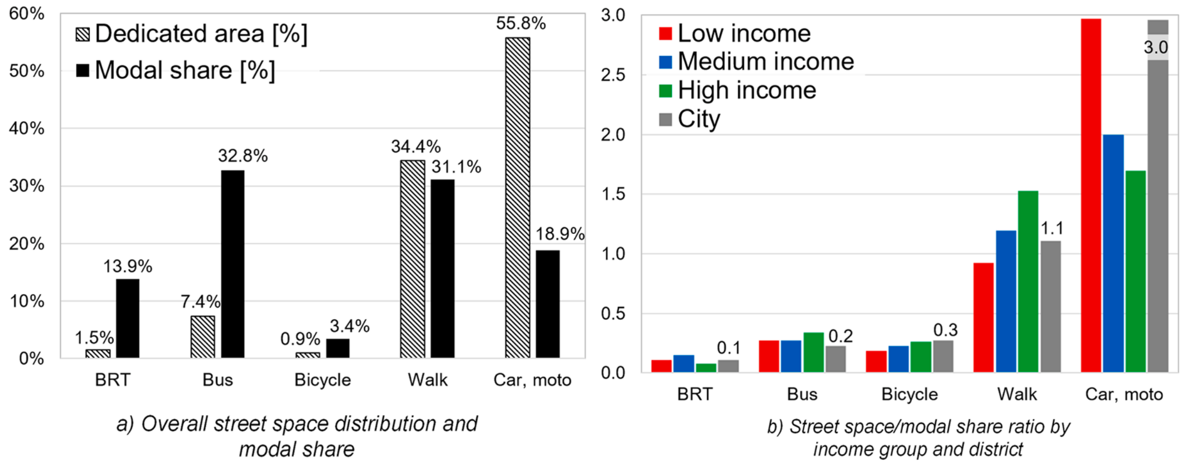


Fig. 3. Street space distribution and daily modal share in Bogotá, Source: own elaboration.

evaluating time-area consumption for an average trip by mode is plotted in Fig. 4a using average travel speed. The data used are from the average values from the Bogotá mobility survey. The Y-axis on the figure is the traveler's consumed area, while the X-axis is the average travel time. In such a way, the resultant areas under the curve represent the time-areas consumed on each transport mode per trip. Thus, Fig. 4a indicates that car and motorcycle travel has the advantage of a shorter horizontal dimension, travel time (except walking and cycling). However, it also has a disadvantage of a much higher vertical dimension, time-area. Note that by increasing the speed in these modes, the time-area consumption is much higher, as is shown in Fig. 4b.

As mode speed increases, the time-area consumed shifts upward, and the consumption itself becomes more considerable. The effect of higher operating speeds causes the time-area to rise more steeply as speed increases, as happens, for example, on urban highways. This last example nicely illustrates the unfairness in the distribution of space in a city: they require a large amount of urban space, are expensive, and only serve a small proportion of the citizens.

As a complement, the results from Eq. (1) are presented graphically in Fig. 4b. There is an optimal point in space consumption per passenger, particularly in cars and motorcycles. However, those optimum are local minimums since they depend on the case study values of travel distance, occupation, and vehicle size. This type of diagram is very revealing about the street space consumption by transport mode. In summary, despite the low average speeds in the city, the individual and motorized transport modes are the most inefficient in space consumption. The time-area per pax-km consumed versus speed for different transport modes using average values for Bogotá shown in Table 2. This table summarizes the values assumed and some calculated results.

Another hint of unfair distribution of street space has to do with the area dedicated to roads and the private vehicle share. This can be related to land consumption per inhabitant, which is directly derived from the population density. In Bogotá, on average, each inhabitant has 51.3 m^2 available urban space, as is shown in Fig. 5a. The implication of this is clear: the smaller the consumption of land per capita, the more disruptive the personal car is as the primary transport mode. These results also show that the wealthy districts have more land and more street space per inhabitant.

To elaborate more on the above, we performed an ANOVA to test the differences between averages of land and street space per capita considering income groups. We found significant differences between average land per capita at the 90% confidence level. Then, we performed a Tukey's HSD test for multiple comparisons to confirm that high-income districts have higher land per capita available than low-income inhabitants (Tukey HSD mean difference = 28.65, p = 0.045).

At the city level, there is a competition for street space between the different types of facilities. The more space devoted to roads, the less area is available for sustainable transport modes. As shown in Fig. 5b, the more space there is allocated for roads, the less space there is for sidewalks, bicycle paths, and BRT corridors. This is also evident when private motorized vehicles are compared with the space destined to active modes (pedestrians and cyclists) and public transport.

Fig. 6 shows the average area's variability per trip and modal share according to the income group. Boxplots were used to represent the average area's distribution per trip and modal share by income groups. The results presented in Fig. 6a show that in low-income districts, the area consumed per trip in private modes is much higher than in other income zones, despite more walking trips in these districts (Fig. 6b). Using ANOVA, we found that space consumed per trip in private modes and walking trips significantly differ by income group. Tukey's HSD tests identified significant differences, at the 90% confidence level, between space consumed per trip in

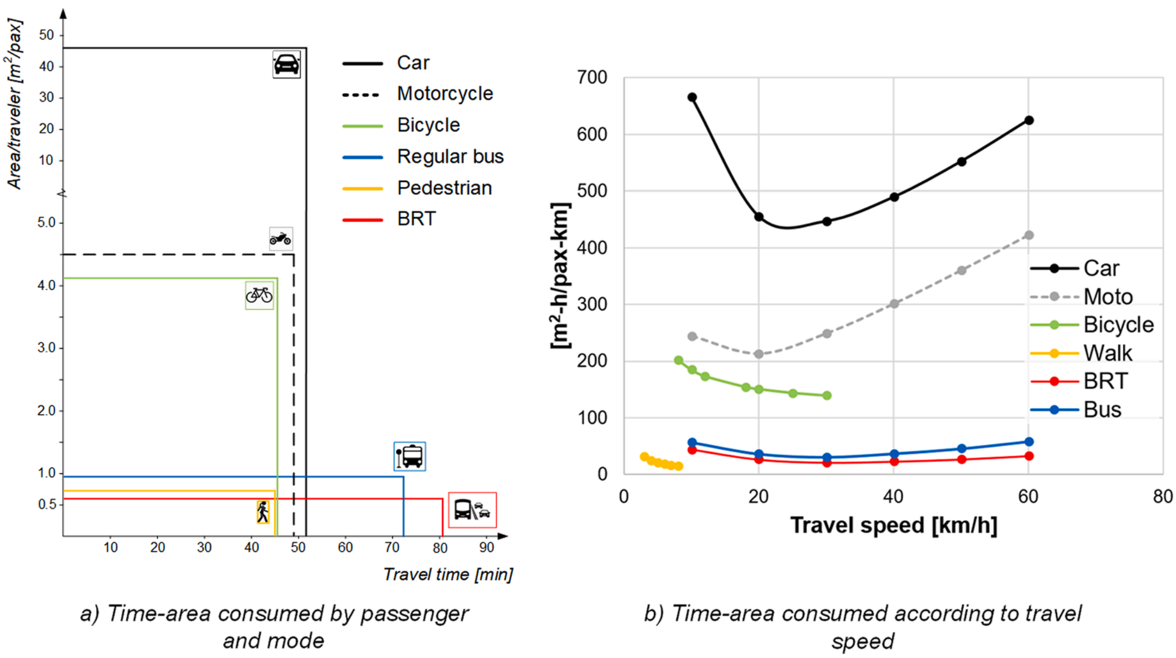
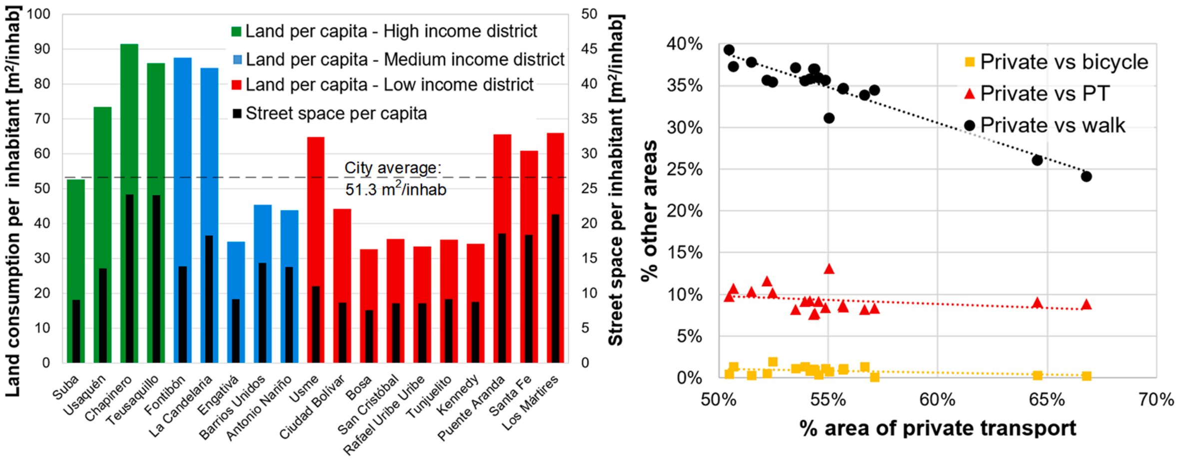


Fig. 4. Time-area consumed per passenger on average trips using different mode choices, Source: own elaboration.

Table 2
Average values used in the time-area calculation.

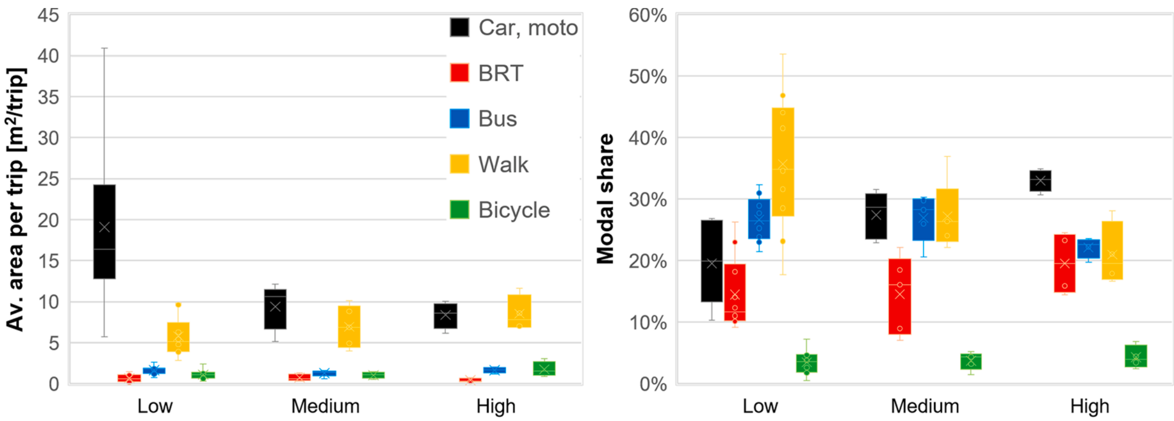
	Car	BRT	Bus	Pedestrian	Bicycle	Motorcycle
Veh. length [m]	4.2	18	11	0.6	1.3	1.9
Occupation [pax/veh]	1.2	128	50	1	1	1
Travel dist. [km]	8.3	12.4	9.4	2.4	7.1	10.2
Travel speed [km/h] *	9.6	9.3	7.7	3.2	9.3	12.5
Right-of-way [m]	3.5	3.6	3.6	1.0	1.3	1.8

* It is important to note that the speed ranges analyzed for each mode are not equal but are dependent on real operational speeds for the type of vehicle in Bogotá. In the car, motorcycle, bus, and BRT, the speed varies from 10 to 60 km per hour. The range goes from 8 to 30 km per hour for the bicycle, and from 2 to 8 km per hour for the pedestrians.



a) Average land consumption per district b) Street space competition

Fig. 5. Land consumption and street space by district, Source: own elaboration.



a) Avg. area/trip by income group b) Modal share by income group

Fig. 6. Boxplots of land consumption and modal share by income at the district level, Source: own elaboration.

private modes by high- and low-income groups (Tukey HSD mean difference = 10.72, p = 0.071). Also, we found a significant difference between medium- and low-income districts (Tukey HSD mean difference = 9.69, p = 0.079).

Similarly, the share of trips in private modes is significantly higher for the wealthiest (Tukey HSD mean difference = 0.13, p = 0.001) and the medium-income groups (Tukey HSD mean difference = 0.08, p = 0.030) compared to low-income districts. There is also a significant difference between walking trips performed by high- and low-income inhabitants (Tukey HSD mean difference = 0.15, p = 0.036). Moreover, the average area per trip does not align with the trip proportion in any income group. This suggests an unfair distribution of space, which is not adequate to meet each transport mode's demand.

In summary, these results show that compared with the rest, the average space consumed about the number of trips per mode is statistically more significant in private transport in the low-income districts. Furthermore, these districts are denser, where there is less land per capita. There is much more space dedicated to the car and motorcycle and less to pedestrians and cyclists, which account for 55% of trips. There are 1.52 times more bicycle path areas in the medium- and high-income districts than the low-income districts.

Private car and motorcycle users tend to put the highest claim on limited street space resources. Fig. 7a displays estimated costs by different income groups of districts considering all facility types. This figure highlights that the value of urban space dedicated to road space has been much higher than that of other modes. Despite the famous and significant investments in public transport and bicycle infrastructure during recent years in Bogotá, the value of urban space is still a long way away from that observed for private transport. Together, infrastructure costs for BRT and bicycle paths do not represent even 1% of the total value of urban space in the city. This figure suggests that the city has given priority to providing space aimed at promoting car and motorcycle mobility, to the detriment of sustainable transport modes. It is essential to acknowledge that this figure does not discount the urban space value's time dimension. Considering the above, it is expected that the road space will be greater since it has been built for decades, while the BRT system only operates since 2000. Indeed, the city has reinforced cycling through the construction of bicycle lanes during the last two decades. Although using a discount for the time dimension may be advisable for further research, this figure shows vast differences in road and sidewalks costs.

We estimated Lorenz curves considering the population to be visible the distributional effects regarding tax collection from car ownership in the 2017–2019 period and road space. Following a similar approach to that suggested by Guzman et al. (2017b), we found that vehicle ownership revenues are not evenly distributed across the population. Instead, they focus on a small and privileged segment that owns a vehicle. However, the road space distribution is more even across the city, which suggests that car users have a more uniform layout of road space to complete their trips. Fig. 7b shows that 70% of the population contributes only nearly 30% of what is collected in vehicle ownership taxes. However, considering the considerable space provided to roads across the city, which is higher compared to other modalities regardless of the income group and the district, as discussed earlier, we can argue that the privileged minority not only pays the taxes but also "buys" the space to mobilize across the city.

6. Discussion and recommendations

Although non-motorized forms of urban mobility such as walking are recognized as an equitable and -largely- inclusive mode (Forsyth and Southworth, 2008), our analysis of Bogotá suggests it is lower in the historical list of priorities for space allocation in the city. Earlier research in the local context has pointed at walking and connectivity at the local scale playing a significant role in accessing the city's population to non-mandatory opportunities (Oviedo and Guzman, 2020). However, urban environments in Bogotá are configured to accommodate private vehicles first.

By incorporating a justice lens to examine the distribution of urban space, it is possible not only to question the patterns for the allocation of urban infrastructure for mobility in a city like Bogotá but to challenge the principles of cost minimization -for a select group of users- underpinning them (Zheng and Geroliminis, 2013). Findings suggest a more central role for walking in urban and transport planning can help redress the spatial mismatch of opportunities that is evident in the local context, serving as a supporting structure for long-term transformations such as promoting mixed land use, dense, compact, and well-planned accessible development (Guzman et al., 2020). However, Bogotá's example also sheds light on how long it has taken the city to recognize the need to rethink how space is allocated for different modes of transport and the citizens that make use of them. In line with Gössling's arguments, in similar contexts of the Global South, improving the current distribution in the use of the existing street space could increase fairness in access to the city (Gössling, 2016).

Transport justice arguments associated with space distribution can also illustrate the influence of negative perceptions of walking as a mode of transport associated with poverty and the aspirations many citizens have to own a car (Lucas and Porter, 2016) or a motorcycle. The story that the Bogotá case seems to have told its citizens for years is that if you own a car, the city will accommodate better your needs than if you walk, cycle or use public transport. To redistribute space is, therefore, an explicit action towards justice. In low- to middle-income countries, where car availability remains comparatively low, walking is more reflective of need rather than choice since a significant proportion of adults walk because they have no other affordable modes of transport. Our findings contribute to a current debate challenging car-centric planning systems, supporting the need to redirect urban development trajectories towards promoting public transport, walking, and cycling (see Szell, 2018) while considering the uniqueness of low- and middle-income cities in the Global South.

The use of clear distributional indicators such as those presented in Fig. 7 adds an urban management dimension to the relatively evident finding that urban spaces are used mainly by motorized transport. Most of the time, they are congested. By making explicit the level of public expenditure associated with increasing the supply of streets in consolidated urban zones, we are also contributing a nuanced perspective to debates about transport-driven inequalities (Delbosc and Currie, 2011b; Guzman et al., 2017b).

Methods presented in Section 5 have the potential to be operationalized as a planning tool in the Bogotá context. Considering that time-space occupancy and distribution of the street space is a shared decision between the urban development and urban mobility areas of local government, introducing metrics such as those shown in our analysis into the definition of budgets for public infrastructure investment at the beginning of each fiscal period can go a long way in achieving a fairer distribution of resources. Such metrics can serve as 'justice tests' to otherwise technical and financial decisions, introducing a much-needed social dimension that increases accountability and coherence in the planning process.

The application of transport justice ideas to the fair distribution of streets in a city such as Bogotá sheds light on the need to balance transport systems' injustices, such as the selective immobilities induced by mainstream transport planning (Levy, 2015). The transport

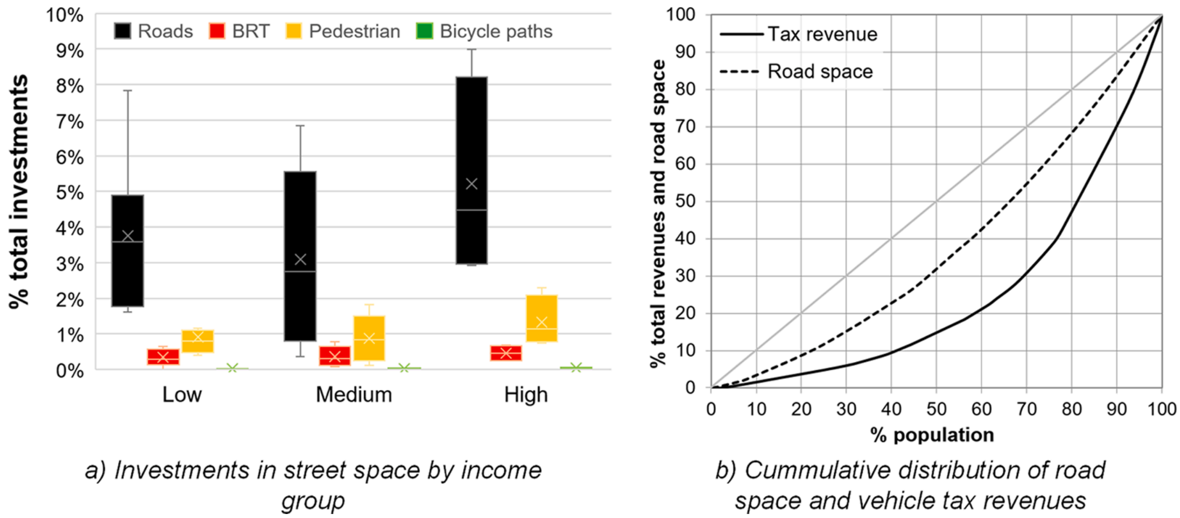


Fig. 7. Investment costs and tax revenues, Source: own elaboration.

justice framework as operationalized in this study to inform a critical examination of a spatially and socioeconomically differentiated availability and access to space adds to social and sustainability concerns in modern transport planning (Jian et al., 2020). While less politically charged than debates around mobility justice, our analysis has intrinsic value for local practice given the stronghold the traditional transport paradigm has in Bogotá's systems for urban space distribution. The fair distribution of urban space is, consequently, a significant challenge for authorities and urban planners. Structural asymmetries in the use and enjoyment of such space lead to inequalities in the rights and freedoms of who, when, and how to use it. However, these inequalities do not occur in a vacuum with the distribution of a high amount of capital investment (Banister and Berechman, 2001) being at the core of the observable inequalities in the previous section.

Our findings are an empirical illustration of a paradigm shift's urgency to incorporate a socially nuanced mobility systems design into transport investment processes. Poor infrastructure and the high rates of death and injury of pedestrians and cyclists are concerning, which makes it essential to examine this paper along with other valuable research exposing further transport injustices (Cervero et al., 2009; Guzman and Oviedo, 2018; Wang et al., 2019) and infrastructure quality (Medaglia et al., 2020) in the local context. The large imbalances between the supply of infrastructure in high-value areas of the city while the provision of connectivity bypasses poorer, less-attractive neighborhoods have contributed to such externalities (Oviedo and Dávila, 2016). Therefore, urban space distribution is a crucial factor in improving transport justice. While our analysis does not directly address the issue of power, the operationalization of the transport justice framework and the resulting evidence can be leveraged to question the power imbalances underpinning measurable differences in physical infrastructure and investments targeting different user groups.

Wealthier groups, who also constitute the largest share of the city's private vehicle fleet, the people who have more cars than the rest of the population (20% of the population owns 45% of car fleet), have better access and provision of urban space for urban mobility adapted to their needs. The distribution of space for different forms of urban mobility in Bogotá reflects the implicit biases in the historical priorities of planning and provision of infrastructure and public space in the city and the immense power imbalances between user groups of different modes. Car users hold more power and influence, shaping urban space more effectively to suit their needs. Such power and influence are sufficient to supersede often collective priorities such as public transport or non-motorized connectivity. In particular, our findings can inform challenges to the power and influence of private motorized vehicle users in transport decision-making.

A potential turning point in the distribution of space is the COVID-19 pandemic and its associated lockdown measures to reduce contagion risk. In Bogotá, the restrictions imposed in response to the pandemic have far-reaching implications given the marked spatial and social inequalities in the city. Local data reports that a large share of the low-income population cannot carry out their main activity from home and nearly 20% have stopped doing their main activity altogether (Guzman et al., 2021). One of the pandemic's most apparent consequences is the inequality in the choice of those that can and cannot access their livelihoods from home and the spatial distribution of opportunities across the city. For the poor, immobility is not a choice. In this regard, the unfair distribution of space can deepen inequalities in the available space for safe circulation and access to essential opportunities. The expanded city center concentrates most hospitals, schools, and other vital facilities, requiring more space for a larger share of the population, presenting a challenge beyond the inequality illustrated by the results. The spatial imbalances in accessibility may carry long-term decreases in quality of life and well-being for those at higher risk of being negatively affected by the pandemic. This can present an opportunity for local governments to rethink the priorities in investment in urban space to achieve a fairer distribution of space supported not only by equality and sustainability but public health arguments in favor.

7. Conclusions

This research provides a method such as time-area occupancy of estimating and mapping injustices in how urban street space is allocated. This research also highlights injustices concerning street space and its use in a dense city like Bogotá. There is evidence of an unfair distribution of street space that favors private motor vehicles over public transport, walking, and cycling. Private and motorized modes can play an essential role in urban transport for segments of the population and specific contexts. However, Bogotá's recurrent problems of historical planning decisions have favored private transport with implicit negative implications for justice in the local context. The clear imbalance in terms of space provision in favor of a minority of private vehicle users can be related to much empirical and conceptual research highlighting inequalities for almost all transport users concerning accessibility, affordability, and overall well-being (Guzman and Oviedo, 2018; Oviedo and Guzman, 2020; Vecchio et al., 2020). Although it is true that in a city like Bogotá, with low car-ownership rates, the greedy consumption of urban space by cars is evident, caution should be exercised when using this methodology in cities with high rates of car-ownership even amongst the poorest segments of the population.

Moreover, as with other cases across the region, the evolution of the network of non-motorized infrastructure has first concentrated in high attractiveness areas and with a concentration of commercial, economic, and cultural opportunities, which also tend to house mostly higher socioeconomic population groups. While most of the population in Bogotá are by and large users of public transport, cycling, and walking, they are often excluded from planning decisions relevant to their mobility and access. Budget decisions are centralized and do not often involve rigorous diagnoses at the meso and macro scale, leading to over-investment in specific parts of the city while others remain underserved or disconnected. Such a reality is reflected by findings in this paper, pointing to the need for measures that could both support walking and cycling with the provision of more and better spaces while restricting the use of private motor vehicles.

Therefore, to pursue justice in the distribution of space for urban mobility in a city such as Bogotá would entail sufficient political and technical leadership to make decisions that may be politically unpopular. However, as documented by Gilbert, Bogotá's history has shown that under the right circumstances and with sufficient political will, strides toward more sustainable urban transport systems have been possible (Gilbert, 2015, 2008), while also cautioning there is a need for a consistent vision to maintain the traction of positive transformations in the long term. Justice can be a common thread to guide such decisions and positive urban transformations, calling for more research that may provide additional evidence on the current inequalities, and practices regarding investment and policies, as well as uncovering new ways to redress such inequalities through more inclusive planning and decision-making.

Acknowledgments

The authors would like to thank the Vice Presidency of Research & Creation's Publication Fund at Universidad de los Andes for its financial support. We also thank to the Bogotá Urban Planning Department (www.sdp.gov.co), for the general support given for the development of this study through the agreement 369 of 2018.

References

Arellana, J., Saltarín, M., Larrañaga, A.M., Alvarez, V., Henao, C.A., 2020. Urban walkability considering pedestrians' perceptions of the built environment: a 10-year review and a case study in a medium-sized city in Latin America. Transp. Rev. 40, 183–203. https://doi.org/10.1080/01441647.2019.1703842.

Banister, D., 2008. The sustainable mobility paradigm. Transp. Policy 15, 73–80. https://doi.org/10.1016/j.tranpol.2007.10.005.

Banister, D., Berechman, Y., 2001. Transport investment and the promotion of economic growth. J. Transp. Geogr. 9, 209–218. https://doi.org/10.1016/S0966-6923(01)00013-8.

Beyazit, E., 2011. Evaluating Social Justice in Transport: Lessons to be Learned from the Capability Approach. Transp. Rev. 31, 117–134. https://doi.org/10.1080/01441647.2010.504900.

Boyce, J.K., Zwickl, K., Ash, M., 2016. Measuring environmental inequality. Ecol. Econ. 124, 114–123. https://doi.org/10.1016/j.ecolecon.2016.01.014.

Bruun, E.C., Vuchic, V.R., 1995. Time-area concept: Development, meaning, and applications. Transp. Res. Rec. 1499, 95–104.

Caprotti, F., Cowley, R., Datta, A., Broto, V.C., Gao, E., Georgeson, L., Herrick, C., Odendaal, N., Joss, S., 2017. The New Urban Agenda: key opportunities and challenges for policy and practice. Urban Res. Pract. 10, 367–378. https://doi.org/10.1080/17535069.2016.1275618.

Cervero, R., Sarmiento, O.L., Jacoby, E., Gomez, L.F., Neiman, A., 2009. Influences of Built Environments on Walking and Cycling: Lessons from Bogotá. Int. J. Sustain. Transp. 3, 203–226. https://doi.org/10.1080/15568310802178314.

Cook, N., Butz, D., 2018. Mobilities, Mobility Justice and Social Justice, Mobilities, Mobility Justice and Social Justice. Routledge. https://doi.org/10.4324/9780815377047.

Copenhagenize, 2014. The Arrogance of Space [WWW Document]. URL http://www.copenhagenize.com/search?q=arrogance+of+space.

Creutzig, F., Javaid, A., Soomauroo, Z., Lohrey, S., Milojevic-Dupont, N., Ramakrishnan, A., Sethi, M., Liu, L., Niamir, L., Bren d'Amour, C., Weddige, U., Lenzi, D., Kowarsch, M., Arndt, L., Baumann, L., Betzien, J., Fonkwa, L., Huber, B., Mendez, E., Misiou, A., Pearce, C., Radman, P., Skaloud, P., Zausch, J.M., 2020. Fair street space allocation: ethical principles and empirical insights. Transp. Rev. 40, 711–733. https://doi.org/10.1080/01441647.2020.1762795.

Delbosc, A., Currie, G., 2011a. Using Lorenz curves to assess public transport equity. J. Transp. Geogr. 19, 1252–1259. https://doi.org/10.1016/j.jtrangeo.2011.02.008.

Delbosc, A., Currie, G., 2011b. The spatial context of transport disadvantage, social exclusion and well-being. J. Transp. Geogr. 19, 1130–1137. https://doi.org/10.1016/j.jtrangeo.2011.04.005.

Dimitriou, H., Gakenheimer, R., 2012. Urban transport in the developing world: A handbook of policy and practice. Edward Elgar Pub, Cheltenham, UK.

Dong, X., 2019. Martens: Transport Justice: Designing Fair Transportation Systems. J. Am. Plan. Assoc. 85, 75–76. https://doi.org/10.1080/01944363.2018.1504574.

Ernste, H., Martens, K., Schapendonk, J., 2012. The Design, Experience and Justice of Mobility. Tijdschr. voor Econ. en Soc. Geogr. 103, 509–515. https://doi.org/10.1111/j.1467-9663.2012.00751.x.

Fainstein, S.S., 2014. The just city. Int. J. Urban Sci. 18, 1–18. https://doi.org/10.1080/12265934.2013.834643.

Forsyth, A., Southworth, M., 2008. Cities Afoot—Pedestrians, Walkability and Urban Design. J. Urban Des. 13, 1–3. https://doi.org/10.1080/13574800701816896.

Fraser, N., 1998. Social justice in the age of identity politics: Redistribution, recognition and participation, Discussion Papers, Research Unit: Organization and Employment, FS I 98-108. Berlin Social Science Center.
Gilbert, A., 2015. Urban governance in the South: How did Bogotá lose its shine? Urban Stud. 52, 665–684. https://doi.org/10.1177/0042098014527484.
Gilbert, A., 2008. Bus Rapid Transit: Is Transmilenio a Miracle Cure? Transp. Rev. 28, 439–467. https://doi.org/10.1080/01441640701785733.
Gössling, S., 2016. Urban transport justice. J. Transp. Geogr. 54, 1–9. https://doi.org/10.1016/j.jtrangeo.2016.05.002.
Gössling, S., Schröder, M., Späth, P., Freytag, T., 2016. Urban Space Distribution and Sustainable Transport. Transp. Rev. 36, 659–679. https://doi.org/10.1080/01441647.2016.1147101.
Güneralp, B., Reba, M., Hales, B.U., Wentz, E.A., Seto, K.C., 2020. Trends in urban land expansion, density, and land transitions from 1970 to 2010: a global synthesis. Environ. Res. Lett. 15, 044015 https://doi.org/10.1088/1748-9326/ab6669.
Guzman, L.A., Arellana, J., Oviedo, D., Moncada, C.A., 2021. COVID-19, activity and mobility patterns in Bogotá. Are we ready for a '15-minute city'? Travel Behav. Soc. 24, 245–256. https://doi.org/10.1016/j.tbs.2021.04.008.
Guzman, L.A., Bocarejo, J.P., 2017. Urban form and spatial urban equity in Bogota, Colombia. Transp. Res. Procedia 25, 4491–4506. https://doi.org/10.1016/j.trpro.2017.05.345.
Guzman, L.A., Oviedo, D., 2018. Accessibility, affordability and equity: Assessing 'pro-poor' public transport subsidies in Bogotá. Transp. Policy 68, 37–51. https://doi.org/10.1016/j.tranpol.2018.04.012.
Guzman, L.A., Oviedo, D., Bocarejo, J.P., 2017a. City profile: The Bogotá Metropolitan Area that never was. Cities 60, 202–215. https://doi.org/10.1016/j.cities.2016.09.004.
Guzman, L.A., Oviedo, D., Rivera, C., 2017b. Assessing equity in transport accessibility to work and study: The Bogotá region. J. Transp. Geogr. 58, 236–246. https://doi.org/10.1016/j.jtrangeo.2016.12.016.
Guzman, L.A., Peña, J., Carrasco, J.A., 2020. Assessing the role of the built environment and sociodemographic characteristics on walking travel distances in Bogotá. J. Transp. Geogr. 88, 102844 https://doi.org/10.1016/j.jtrangeo.2020.102844.
Hananel, R., Berechman, J., 2016. Justice and transportation decision-making: The capabilities approach. Transp. Policy 49, 78–85. https://doi.org/10.1016/j.tranpol.2016.04.005.
IDU, 2020. Precios Unitarios de Referencia 2019-II + Mano de Obra [WWW Document]. URL https://www.idu.gov.co/page/siipviales/economico/portafolio.
Jang, S., An, Y., Yi, C., Lee, S., 2017. Assessing the spatial equity of Seoul's public transportation using the Gini coefficient based on its accessibility. Int. J. Urban Sci. 21, 91–107. https://doi.org/10.1080/12265934.2016.1235487.
Jian, I.Y., Luo, J., Chan, E.H.W., 2020. Spatial justice in public open space planning: Accessibility and inclusivity. Habitat Int. 97, 102122 https://doi.org/10.1016/j.habitatint.2020.102122.
Jones, P., Lucas, K., 2012. The social consequences of transport decision-making: clarifying concepts, synthesising knowledge and assessing implications. J. Transp. Geogr. 21, 4–16. https://doi.org/10.1016/j.jtrangeo.2012.01.012.
Karndacharuk, A., Wilson, D.J., Dunn, R., 2014. A Review of the Evolution of Shared (Street) Space Concepts in Urban Environments. Transp. Rev. 34, 190–220. https://doi.org/10.1080/01441647.2014.893038.
Kennedy, C., Miller, E., Shalaby, A., Maclean, H., Coleman, J., 2005. The Four Pillars of Sustainable Urban Transportation. Transp. Rev. 25, 393–414. https://doi.org/10.1080/01441640500115835.
Lefebvre, H., 1996. The right to the city: Writings on Cities. Wiley-Blackwell, Malden, Massachusetts.
Levy, C., 2015. Routes to the just city: Towards gender equality in transport planning. In: Moser, C.O.N. (Ed.), Gender, Asset Accumulation and Just Cities: Pathways to Transformation. Taylor & Francis, p. 15.
Levy, C., 2013. Travel choice reframed: "deep distribution" and gender in urban transport. Environ. Urban. 25, 47–63. https://doi.org/10.1177/0956247813477810.
Lucas, K., 2012. Transport and social exclusion: Where are we now? Transp. Policy 20, 105–113. https://doi.org/10.1016/j.tranpol.2012.01.013.
Lucas, K., Porter, G., 2016. Mobilities and livelihoods in urban development contexts: Introduction. J. Transp. Geogr. https://doi.org/10.1016/j.jtrangeo.2016.07.007.
Manaugh, K., Badami, M.G., El-Geneidy, A.M., 2015. Integrating social equity into urban transportation planning: A critical evaluation of equity objectives and measures in transportation plans in North America. Transp. Policy 37, 167–176. https://doi.org/10.1016/j.tranpol.2014.09.013.
Martens, K., 2020. How just is transportation justice theory? The issues of paternalism and production: A comment. Transp. Res. Part A Policy Pract. 133, 383–386. https://doi.org/10.1016/j.tra.2020.01.012.
Martens, K., 2017. Transport Justice: Designing Fair Transportation Systems. Routledge, New York.
Martens, K., Golub, A., Robinson, G., 2012. A justice-theoretic approach to the distribution of transportation benefits: Implications for transportation planning practice in the United States. Transp. Res. Part A 46, 684–695.
Martens, K., Hurvitz, E., 2011. Distributive impacts of demand-based modelling. Transportmetrica 7, 181–200. https://doi.org/10.1080/18128600903322333.
Medaglia, A.L., Sarmiento, O.L., Guzman, L.A., Cabrales, S.A., Huertas, J.A., Palacio, A., Botero, M., Carvajal, G.A., van Laake, T., Higuera-Mendieta, D., 2020. Level of traffic stress-based classification: A clustering approach for Bogotá, Colombia. Transp. Res. Part D Transp. Environ. 85, 102420 https://doi.org/10.1016/j.trd.2020.102420.
Milieudefensie, 2017. Van wie is de stad? Milieudefensie, Amsterdam.
Mullen, C., Tight, M., Whiteing, A., Jopson, A., 2014. Knowing their place on the roads: What would equality mean for walking and cycling? Transp. Res. Part A Policy Pract. 61, 238–248. https://doi.org/10.1016/j.tra.2014.01.009.
Nello-Deakin, S., 2019. Is there such a thing as a 'fair' distribution of road space? J. Urban Des. 1–17 https://doi.org/10.1080/13574809.2019.1592664.
Oviedo, D., Dávila, J.D., 2016. Transport, urban development and the peripheral poor in Colombia - Placing splintering urbanism in the context of transport networks. J. Transp. Geogr. 51, 180–192.
Oviedo, D., Guzman, L.A., 2020. Revisiting Accessibility in a Context of Sustainable Transport: Capabilities and Inequalities in Bogotá. Sustainability 12, 4464. https://doi.org/10.3390/su12114464.
Pereira, R.H.M., Schwanen, T., Banister, D., 2017. Distributive justice and equity in transportation. Transp. Rev. 37, 170–191. https://doi.org/10.1080/01441647.2016.1257660.
Rawls, J., 1999. A Theory of Justice, revised ed. Harvard University Press, Boston.
Samoli, E., Stergiopoulou, A., Santana, P., Rodopoulou, S., Mitsakou, C., Dimitroulopoulou, C., Bauwelinck, M., de Hoogh, K., Costa, C., Marí-Dell'Olmo, M., Corman, D., Vardoulakis, S., Katsouyanni, K., 2019. Spatial variability in air pollution exposure in relation to socioeconomic indicators in nine European metropolitan areas: A study on environmental inequality. Environ. Pollut. 249, 345–353. https://doi.org/10.1016/j.envpol.2019.03.050.
Santos, G., Behrendt, H., Maconi, L., Shirvani, T., Teytelboym, A., 2010. Part I: Externalities and economic policies in road transport. Res. Transp. Econ. 28, 2–45. https://doi.org/10.1016/j.retrec.2009.11.002.
Soja, E.W., 2010. Why Spatial? Why Justice? Why L.A.? Why Now?, Seeking Spatial Justice. University of Minnesota Press. https://doi.org/10.5749/minnesota/9780816666676.003.0002.
Szell, M., 2018. Crowdsourced Quantification and Visualization of Urban Mobility Space Inequality. Urban Plan. 3, 1–20. https://doi.org/10.17645/up.v3i1.1209.
Uteng, T.P., Lucas, K., 2017. Urban Mobilities in the Global South, Urban Mobilities in the Global South. Routledge. https://doi.org/10.4324/9781315265094.
Vanoutrive, T., Cooper, E., 2020. How just is transportation justice theory? The issues of paternalism and production: A rejoinder. Transp. Res. Part A Policy Pract. 133, 387–390. https://doi.org/10.1016/j.tra.2020.01.011.
Vanoutrive, T., Cooper, E., 2019. How just is transportation justice theory? The issues of paternalism and production. Transp. Res. Part A Policy Pract. 122, 112–119. https://doi.org/10.1016/j.tra.2019.02.009.
Vasconcellos, E.A., 2014. Urban Transport Environment and Equity, Urban Transport Environment and Equity: The Case for Developing Countries. Routledge, London. https://doi.org/10.4324/9781315071756.

Vecchio, G., Tiznado-Aitken, I., Hurtubia, R., 2020. Transport and equity in Latin America: a critical review of socially oriented accessibility assessments. Transp. Rev. 40, 354–381. https://doi.org/10.1080/01441647.2020.1711828.
Wang, X., Rodríguez, D.A., Sarmiento, O.L., Guaje, O., 2019. Commute patterns and depression: Evidence from eleven Latin American cities. J. Transp. Heal. 14, 100607 https://doi.org/10.1016/j.jth.2019.100607.
Zheng, N., Geroliminis, N., 2013. On the distribution of urban road space for multimodal congested networks. Transp. Res. Part B Methodol. 57, 326–341. https://doi.org/10.1016/j.trb.2013.06.003.