

PEDRO DA CUNHA REGO LOGIODICE

Urban mobility injustice

São Paulo
2023

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Dissertação apresentada à Escola Politécnica da Universidade de São Paulo para obtenção do Título de Mestre em Ciências.

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Versão Corrigida

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Área de Concentração:

Engenharia de Transportes

Orientador:

Prof^a Mariana Abrantes Giannotti

São Paulo
2023

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To Marina Harkot (in memoriam), who inspired me to think about mobility beyond transport.

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'[...]all of you who suffer from lack of transport, all of you who have your rights violated, you exist and you are valuable to us.'

Silvio Almeida in the inauguration speech as Brazil's Minister of State for Human Rights in January 2023.

ABSTRACT

Justice has emerged as a significant concern in urban mobility and accessibility. Although some scholars adopted the ‘distributive justice’ approach to empirically study accessibility at the urban scale, a greater extent of theoretical literature has demonstrated the limitations of this approach to understanding injustice, thereby stating the requirement of a ‘mobility justice’ perspective. For the bodily scale, we propose an urban mobility relational approach departing from concrete injustices, understood through the lenses of oppression between social groups. To operationalize this approach for an urban study, we propose a new mobility-accessibility juxtaposing framework that enables disentangling possible interrelations between various urban mobilities regimes. Using smart card data of public transport from the Global South city of São Paulo (Brazil), we performed an empirical evaluation that measured three central dimensions of mobility (time duration, fare cost, and crowding) from transit users that home zones have distinct shares of races and classes. Regarding the time duration of trips, we found that in advantageous mobility situations (from 1h to 2h), all the home zones are majority white, whereas in the disadvantageous (above 3h30), all the zones are majority black. Regarding cost, in advantageous mobility fares (below 9 Brazilian reals), all the zones are majority white, whereas at the disadvantageous (above 18 Brazilian reals), all the zones are majority black. Finally, we adopted a novel approach to capturing the crowding conditions from the user’s perspective, considering the commuting duration under a minimum in-vehicle passenger density threshold. This analysis reveals that situations of no overcrowding (below 6 passenger/m²) are faced only by majority white zones, whereas above 30 minutes in overcrowded vehicles are only faced by majority lower-class zones. The presented findings suggest that race and class inform, to a large extent, the mobility regimes by public transport in the city of São Paulo today. The new theoretical framework and the methodological innovations presented point towards a novel perspective for urban mobility research and transport policies concerned with structural mechanisms that reproduce urban mobility injustice.

Keywords – urban mobility, accessibility, justice.

RESUMO

A justiça emergiu como uma preocupação na mobilidade e na acessibilidade urbana. Embora alguns pesquisadores tenham adotado a abordagem de "justiça distributiva" para estudar empiricamente a acessibilidade na escala urbana, parte da literatura teórica demonstrou as limitações desta abordagem para compreender a injustiça, afirmando assim a exigência de uma perspectiva de "justiça de mobilidade". Para a escala do corpo, propomos uma abordagem relacional de mobilidade urbana partindo de injustiças concretas, compreendidas através das lentes de opressão entre grupos sociais. Para operacionalizar esta abordagem para um estudo urbano, propomos uma novo enquadramento teórico que relaciona mobilidade e acessibilidade com o objetivo de desvendar possíveis inter-relações entre diferentes regimes de mobilidade urbana. Usando dados de transações de cartões eletrônicos de transporte público (Bilhete Único) da cidade de São Paulo (Brasil), realizamos uma avaliação empírica que mediu três dimensões centrais da mobilidade (duração do tempo, custo e taxa de ocupação) sob a perspectiva dos usuários de zonas com diferentes raças e classes. Com relação à duração das viagens, constatamos que em situações vantajosas de mobilidade (de 1h a 2h), todas as zonas são resididas por uma população majoritariamente branca, enquanto que nas situações de desvantagem (acima de 3h30), todas as zonas são resididas por populações majoritariamente negras. Com relação ao custo, nas tarifas vantajosas de mobilidade (abaixo de 9 reais), todas as zonas são majoritariamente brancas, enquanto em situações de desvantagem (acima de 18 reais), todas as zonas são majoritariamente negras. Finalmente, adotamos uma nova abordagem para capturar as condições de lotação pela perspectiva do usuário, considerando a duração do trajeto sob um limite de densidade de passageiros dentro do veículo. Esta análise revela que situações de não superlotação (abaixo de 6 passageiros/m²) são enfrentadas apenas por zonas majoritariamente brancas, enquanto deslocamentos acima de 30 minutos em veículos superlotados são enfrentadas apenas por zonas majoritariamente de classe baixa. Os resultados apresentados sugerem que raça e classe informam, em grande medida, os regimes de mobilidade por transporte público na cidade de São Paulo de hoje. O novo enquadramento teórico e as inovações metodológicas apresentadas apontam para uma nova perspectiva de pesquisa sobre mobilidade urbana e políticas de transporte preocupadas com mecanismos estruturais que reproduzem a injustiça da mobilidade urbana.

Palavras-Chave –mobilidade urbana, acessibilidade ao meio físico, justiça.

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LIST OF ABBREVIATIONS

ABTN - *Brazilian National Standards Organization*

GTFS - *General Transit Feed Specification of public transport*

ICT - *Information and Communication Technology*

LA - *Latin America*

OSM - *Open Street Map*

OTP - *Open Trip Planner*

SPTTrans - *São Paulo municipal public bus agency*

TRSE - *Transport Related Social Exclusion*

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1 INTRODUCTION

The governance of how bodies move –or are prevented from moving– is intimately related to challenges at various scales (SHELLER, 2018b). At the planetary scale, climate changes challenge cities to advance on the transition to low-carbon and sustainable transportation (HOPKINS; HIGHAM, 2016). At the regional scale, poor urban accessibility reinforces cumulative inequalities (BITTENCOURT et al., 2021). At the bodily scale, the precarious conditions of movement by public transport. All these mobility concerns may be even more critic considering the upcoming rapid growth in urban population – from 4.2 (in 2018) to 6.7 (2050) billion–, occurring primarily in the shantytowns of less-developed regions (UNITED, 2018). In a context of high inequality gap, poverty level, and environmental risk, the concerns related to urbanization (CALDEIRA, 2017), transport (LUCAS et al., 2016a), and uneven mobilities (SHELLER, 2018a) faced by cities in the Global South are quite distinct from those in cities of developed countries.

Worldwide, the existing literature in the transport field has vastly adopted the concept of urban accessibility to investigate the interplay between land use and transport (GEURS; WEE, 2004), which is a powerful tool for unravelling the spatial inequality at the urban scale (BITTENCOURT et al., 2021). The debate on the current spatial patterns of accessibility was also recently enriched by theories of distributive justice in an effort to inform urban and transport planning (PEREIRA et al., 2017). Despite the importance of accessibility analysis for research and planning, it has the limitation of misrepresenting the bodily scale, failing to capture vital implications that transpire in the current commuting conditions of the urban transport system. Additionally, when misrepresenting the existence of social groups, the transport distributive justice approach may have fallen short in explaining oppressive relations functioning across classes, races, and genders (YOUNG, 1990).

Urban accessibility is an estimation of the potential for interaction from places to other activities in the city (HANSEN, 1959), whereas urban mobility enables measuring the revealed patterns and conditions of how people move when interacting with the city.

To investigate the (the lack of) access to the city and transport infrastructure, in addition to disentangling the spatial inequality at the urban scale, urban mobility at the bodily scale must be considered (SHELLER, 2018b). Urban mobility analysis relates to movement, count of trips, distance covered and speeds (MARTENS, 2012) allowing to identify mobility patterns and inequalities. Nevertheless, for debating justice regarding urban mobility, especially in the Global South, it is critical to shift its understanding from the ‘paradigm of distribution’ (YOUNG, 1990) to the notion of oppression between social groups.

The logic of urbanization in the Global South consists in a set of interrelated processes that implicate citizens and states in the production of highly unequal and heterogenous spaces (CALDEIRA, 2017). Historically, these processes ensured advantageous conditions for the wealth concentration of the best-off groups also by withdrawing the fundamental rights of the worst-off, such as housing and transportation, and more broadly, participation and sharing of benefits from the city (KOWARICK, 1979). Comprehensively, the production of its persistent unequal urban environments is characterized by the contradictory alliance of development and deprivation (MARICATO, 2015), economic growth and poverty (KOWARICK, 2009). Therefore, disclosing current situations in which the rights of specific groups are plundered to sustain the privileges of others (YOUNG, 1990) emerges as a relevant perspective for urban mobility research.

The Mobility Justice (SHELLER, 2018a), which concerns on ‘how power and inequality inform the governance and control of movement, shaping the patterns of unequal mobility and immobility in the circulations of people, resources and information’ (SHELLER, 2018a, p. 30), sheds light to a helpful perspective on how to think urban mobility, especially in cities of the Global South. The deeper understanding of uneven mobilities relates not only to how people move around cities, but also by tracing how racialized and gendered colonial histories are present in (SHELLER, 2018b) the relations between advantageous and disadvantageous regimes of mobility today. The Mobility Justice is a multiscale and overarching theory, therefore demands a careful reflexion on how to operationalize the application of its concepts as well as how to explore related empirical evidence for urban studies.

How to theoretically identify urban mobility regimes, considering both accessibility and mobility? How to investigate and unveil injustice regarding urban mobility? Does empirical evidence (from a Global South city) confirm the existence of relations between privilege and precarious regimes of urban mobility? Reflecting on the questions raised, it was challenging to find a theoretical framework that not only identifies various mobility

regimes but also reflects on the interrelations, connections, and interdependencies between them to identify current injustices. In addition, from an empirical research perspective, to the best of the authors' knowledge, no previous study explored smart card data and spatialized information on social class and race to measure the observed mobility conditions of various social groups to discuss the existing urban mobility injustice.

The study at hand has a twofold objective. Firstly, it proposes a theoretical framework that identifies mobility injustices by relating mobility and accessibility across various urban (im)mobility regimes. This approach enables research on mobility justice to disentangle the interrelationships between different situations of advantage and disadvantage regarding urban mobility. Building on this generalizable framework, which can be applied in diverse contexts, we then conduct an empirical study to incorporate specific aspects related to social and urban structures. Secondly, we aim to provide evidence of unequal and interrelated mobility regimes in São Paulo, Brazil, a Global South city, by analyzing the commuting conditions of different social groups. Overall, we intend to uncover mechanisms that perpetuate injustices in urban mobility by public transport.

To achieve these objectives, we adopt a few innovative methods for both accessibility and mobility analysis. The first consist in computing a threshold to be used at job accessibility analysis based on a smart card data observed mobility patterns. The second is a new method to measure crowding conditions in the public transport from the user perspective. By these and other methods we measure the travel duration, fare cost, and crowding conditions of various class and race, and relate the findings with relevant gender aspects. Although certain scholars have analysed inequalities regarding mobility and accessibility, to the best of authors knowledge, no previous study has applied mobility justice theory to practice in an urban context by measuring uneven mobilities based on smart card data. The new theoretical framework and the methodological innovations presented point towards a novel perspective for urban mobility research and transport policies concerned with structural mechanisms that reproduce urban mobility injustice.

Following this introduction, the mobility-accessibility juxtaposing framework is presented in chapter 2. We detail the research design, including a brief description of the empirical analysis study area, data, and methods in chapter 3. In chapter 4, we discuss the empirical evidence on travel duration, fare cost, and crowding. The findings are compelling to support that the transport literature and urban policies should attend to the various forms of extortion existing across the social groups operating under transport systems.

2 MOBILITY-ACCESSIBILITY JUXTAPOSING FRAMEWORK AS A MEANINGFUL APPROACH FOR UNVEILING URBAN MOBILITY INJUSTICE

Herein, the literature related to accessibility, mobility and justice is briefly reviewed (Section 2.1) as a foundation to establish the proposed theoretical framework (section 2.2).

2.1 Accessibility, mobility, and justice

Since Hansen (1959) first introduced the concept of measuring the potential for interaction with opportunities, ‘urban accessibility’ has emerged as a prominent approach to investigate the ease of access within a city. In principle, accessibility depends on the spatial relationship between land use and mobility systems (GEURS; WEE, 2004), wherein transportation infrastructure and supply enable individuals to commute and accomplish activities in urban areas, such as jobs, education, leisure, etc.

The existence of transport infrastructure does not singularly ensure the possibility of moving (VECCHIO; MARTENS, 2021), as barriers prevail between the individuals and transport system regarding availability, affordability, reliability, and safety (LUCAS et al., 2016b). Therefore, the interaction between supply and demand forms an essential component of accessibility (GEURS; WEE, 2004), expressed as the sum of commute burdens including time, distance, cost, and crowdedness. Recent empirical studies have considered crucial aspects such as supply, crowdedness (ARBEX; CUNHA, 2020), and affordability (BITTENCOURT; GIANNOTTI, 2021) to determine the accessibility of cities in the Global South.

Along with spatiality, time is a pivotal component to understanding and measuring accessibility. The temporal constraints caused by commuting duration, opening hours of establishments or public services, and personal time availability may influence according

to the potential of access to and participation in activities (GEURS; WEE, 2004). The interaction between mobility resources — both public and private (VECCHIO; MARTENS, 2021) — and activities is essential for the time component of accessibility. In particular, households that own private vehicles or foster a budget to avail efficient modes of transport may experience decreased time burdens for moving. Regarding the role of activities, the birth of a child, for instance, may reduce the time available to the family members, because care activities require complex itineraries to manage daily appointments (JIRÓN et al., 2020).

Urban mobility is related to movement, number of trips, distance covered and speeds (MARTENS, 2012). The actual displacement of a commuter depends on omitted, unmeasurable, or difficult-to-measure variables such as fear and discrimination, in addition to observed variables such as transit fares, time expenditure, distance, transport supply, and crowdedness. Certain factors that explain the realisation of a commute transcend transport scope and are related to other resources and capabilities (VECCHIO; MARTENS, 2021), which are largely constituted by racial, class, and gendered structures of power. Thus, mobility or immobility is a social outcome (SHELLER, 2018a), in addition to an individual outcome, because resource and activity roles are far from being randomly allocated among social groups (DAVIS, 2016). For instance, Lucas et al. (2016a) recognises that ‘social exclusion is not always or solely the result of a lack of access to destinations only’ (LUCAS et al., 2016b, p. 486), but it rather depends on the aspects uncovered by transport indicators.

Mobility reflects social inequality (BLANCO et al., 2018). The allocation of resources and responsibilities within the urban scale — considering race and class structure — and at the household level — considering gendered relations — determines the mode and availability of commute (HANSON, 2010). Various social groups encounter uneven amounts of time and fare cost to commute and undertake trips with unequal levels of comfort and safety. Based on the disparity existing in transport levels, scholars have debated justice from political philosophy as a framework to investigate the distributions of transport outcomes (LEVINSON; ERMAGUN, 2021). The literature has comprehensively adopted the theories of ideal justice to discuss the scope of a fair distribution in an ideal society, including approaches such as absolute or minimum need, equality of opportunity, maximin theory of justice, and relative need (PEREIRA et al., 2017; LEVINSON; ERMAGUN, 2021).

The transport distributive justice literature has mainly adopted accessibility analysis to empirically operationalize its discussion. Pereira et al. (2017) claim that the focus

on observed travel behaviour neglects ‘trips that would have been taken were it not for constraints imposed by the transport system or by other economic and social reasons’ (PEREIRA et al., 2017, p. 177), implying that transport accessibility instead of mobility ‘stands out as the most promising focal variable of distributive justice’ (PEREIRA et al., 2017, p. 178). The compelling match between distributive justice approach and accessibility comes to highlight an important limitation of this theoretical perspective which is the understanding that justice is only a matter of spatial distribution among individuals instead of the power relations between social groups.

The excess focus on the interaction between transportation system and land use at urban scale for discussing justice may be explained by the fact that distributive justice approach misrepresents power relations. It has fundamentally adopted individualistic perspectives, either people- or place-based (GEURS; WEE, 2004), that tends to ignore social groups, which implicates a blind analysis towards race, class, and gender (SHELLER, 2018a). The atomisation of groups in individuals may overlook historically rooted issues of current social structures, such as the heritage of colonial and slave societies, that may inform the governance and control of the mobility or immobility of bodies in the city (SHELLER, 2018b).

The criticism over the absence of a relational approach between social groups in the transport research based on distributive justice is consistent with a major debate in the broader literature of political philosophy. The political philosopher Young (1990) argues that contemporary theories of justice are dominated by ‘the distribution paradigm’ that ‘defines social justice as the morally proper distribution of social benefits and burdens among society’s members’ (YOUNG, 1990, p. 16). This reflection on ‘just’ primarily focuses on the end-state patterns of the distribution of goods among individuals, such as wealth and income (RAWLS, 1971), and similarly, urban accessibility in the transport field (PEREIRA et al., 2017).

However, social justice is not only a subject of distribution. Young (1990) illuminates on the vital and structural gaps of the distributive justice approach on the concept of justice that could be systematised in two principal arguments. First, its ontology does not consider the perspectives of social groups in a society by accounting the individual as a unit of analysis, what overshadows the social structure, institutional context, and historical elements that often contribute toward establishing the current distributive patterns. Second, it conceptualises justice in terms of distribution instead of the consequence of establishing oppressive relations between social groups. These two arguments are further detailed and exemplified by situations involving mobility, accessibility, and transport as

a basis for the following theoretical framework proposition.

Social groups such as gender, class, and race are pivotal for understanding justice (SHELLER, 2018a). For instance, the gendered allocation of both responsibilities (HANSON, 2010) and private mobility resources within the household causes significant consequences on the travel patterns and transit speed of female commuters, who typically avail mobility of care (MADARIAGA; ZUCCHINI, 2019) and more affordable modes of transport than their male counterparts (LEVY, 2013). In addition, the social class has implications for the modes, availability, and access of circulation within the city, considering factors such as the affordability of cars (LUCAS et al., 2016a) and public transport fares (VASCONCELLOS, 2005). More importantly, race is a paramount factor of segregation within the territory (ANDERSON, 2010) — and historically, even inside public transport vehicles (PARKS, 1992) — that affects the commuting burdens potentially encountered by various racial groups (BITTENCOURT; GIANNOTTI, 2021).

Also, distributive justice assumes that the only significant relationship between the individuals involves the relative positions within a distribution of goods, and consequently, disregards the existence of social groups and the importance of issues related to oppression between them have in understanding justice (YOUNG, 1990). This methodological limit biases the empirical analysis toward more ‘easily identifiable distributions’ (YOUNG, 1990, p. 24) such as income, and in the transport field, primarily investments (MARTENS, 2012) and potential accessibility (PEREIRA, 2019). Young (1990) argues that rights and opportunities are ‘conditions of enablement rather than possession; it refers to doing more than having’ (YOUNG, 1990, p. 26).

For instance, let us consider ‘job opportunities’ that are widely discussed in accessibility analysis (OWEN; LEVINSON, 2015; BOISJOLY; EL-GENEIDY, 2016; BASTIAANSEN et al., 2020). Paraphrasing Young (1990, p. 26), providing job opportunities entails the allocations of specific material resources—subsidies, land-use development, new transport infrastructure, supply, etc. Presumably, a greater number of resources corresponds to wider opportunities offered to people to access the labour market. However, employment in a new job is primarily a process that occurs in a complex environment of social relations. Depending on the social context, males and females, lower- and upper-class, and black and white often cannot avail equally enabling job opportunities even if an equivalent number of resources has been devoted to their ability to physically access the job. In Young’s words, ‘this does not show that distribution is irrelevant to opportunity, only that opportunity has a wider scope than distribution’ (YOUNG, 1990, p. 26).

In contrast to the theories of ideal justice that dedicate its reflections on what a just society would be, the nonideal theories of justice start from concrete problems since identifying injustices does not depend on a clear definition of a just distribution (ANDERSON, 2010). Inequality and injustice may not be an outcome of the lack or bad formulations of a just distribution ideal, instead it is the consequence of establishing oppressive relations—both historically and socially rooted — as ‘the powerful enact and reproduce their power’ (YOUNG, 1990, p. 32). The concept of oppression is not solely the exercise of tyranny by a ruling group, but a set of societal rules and practices that constitute a restrictive structure of forces and barriers that immobilize and reduce a group of people to be fully human (YOUNG, 2014). Oppression is a structural phenomenon being the consequence of often unconscious assumptions and actions of well-intended people in ordinary interactions of normal process in everyday life. Even though there is always a privileged groups in relation to an oppressed group, an oppressive group need not have a correlated oppressing group (YOUNG, 2014). Meaning that oppression is a systemic phenomenon that could not be eliminated only by getting rid of rulers or privilege groups.

For applying a relational approach to urban mobility, we argue for the need of a frame that enables identifying various mobility regimes and the reflection on the possible interrelations, connections, and interdependencies between them to unveiling current injustices. These mobility regimes consist in the various forms of being mobile or immobile and depend both on accessibility at the urban scale and mobility at the bodily scale. Even though the frame regards only (im)mobility categories, it allows to reflect on power relations considering the existing social markers (e.g., race, class, and gender) and how they inform both the conditions of movement and immobility. The frame aims to be generalizable for any city, being open to the particularities of each place for a historically and socially contextualised reflection on urban mobility.

In sum, the distributive justice approach narrows the understanding of justice as the morally proper distribution among individuals and in transport field is operationalized mainly through accessibility analysis at the urban scale. For the bodily scale, we propose an urban mobility relational approach departing from concrete injustices, understood through the lenses of oppression between social groups. Based on the current discussion, we argue that injustice regarding urban mobility is not solely produced by unequal distribution, but instead, it is a process that reproduces structural forms of oppression. Thus, considering the existing racist, classist, and oppressive gendered structures, we propose a novel framework for urban mobility studies that integrates accessibility and mobility according to the perspective of interrelations—both at urban and bodily scales.

This approach aims to assist in identifying and investigating the processes through which the (im)mobility of certain groups nonreciprocally supports the privilege (im)mobility of others, which is presented as follows.

2.2 Mobility-accessibility juxtaposing framework

A highly accessible location is beneficial for its dwellers, considering the ease of commuting, and therefore, successfully reaching activities. However, this principle of ‘the more, the better’ is not true at all instances for mobility. Groups may experience high levels of mobility and uneven situations in terms of commuting burdens and degrees of choice or freedom. For instance, certain groups commute long distances in the city as a coping strategy (LAW, 1999), because they cannot afford to live in proximity of the city’s opportunities (KOWARICK, 1979), or even, perform numerous trips to deliver goods and food under precarious conditions (MINARELLI, 2020). Therefore, high mobility does not necessarily imply a greater level of well-being. Simultaneously, the immobility of specific bodies may be an outcome of drastically distinct situations. Certain groups may be restricted from moving owing to social exclusion and unaffordability of transport. In contrast, others may experience immobility as a choice to not move, considering the possibility of information and communication technology (ICT) that enables certain groups to access goods, services, and work in cyberspace (LEVINSON; ERMAGUN, 2021). Therefore, mobility analysis requires a thorough understanding of the relational nature of movement.

In consideration of the degree of mobility and accessibility, we propose two advantages and two disadvantages’ situations as analytical categories to investigate. We discuss the interrelation of mobility or immobility of bodies in the city based on four categories: ‘privileged mobility’, ‘chosen immobility’, ‘compulsory immobility’, and ‘precarious mobility’ (Figure 1). ‘Compulsory immobility’ and ‘precarious mobility’ are disadvantageous situations experienced by groups that generally face urban extortions in the form of collective goods deprivation (KOWARICK, 1979), such as the inexistence of affordable and adequate transport services. On the contrary, ‘privilege mobility’ and ‘chosen immobility’ are situations of advantage that occur in case bodies from dominant groups exhibit the freedom to decide on whether to move, which results from a sum of benefits from collective goods operationalised – directly or indirectly – at the cost of bodies pertaining to oppressed groups.

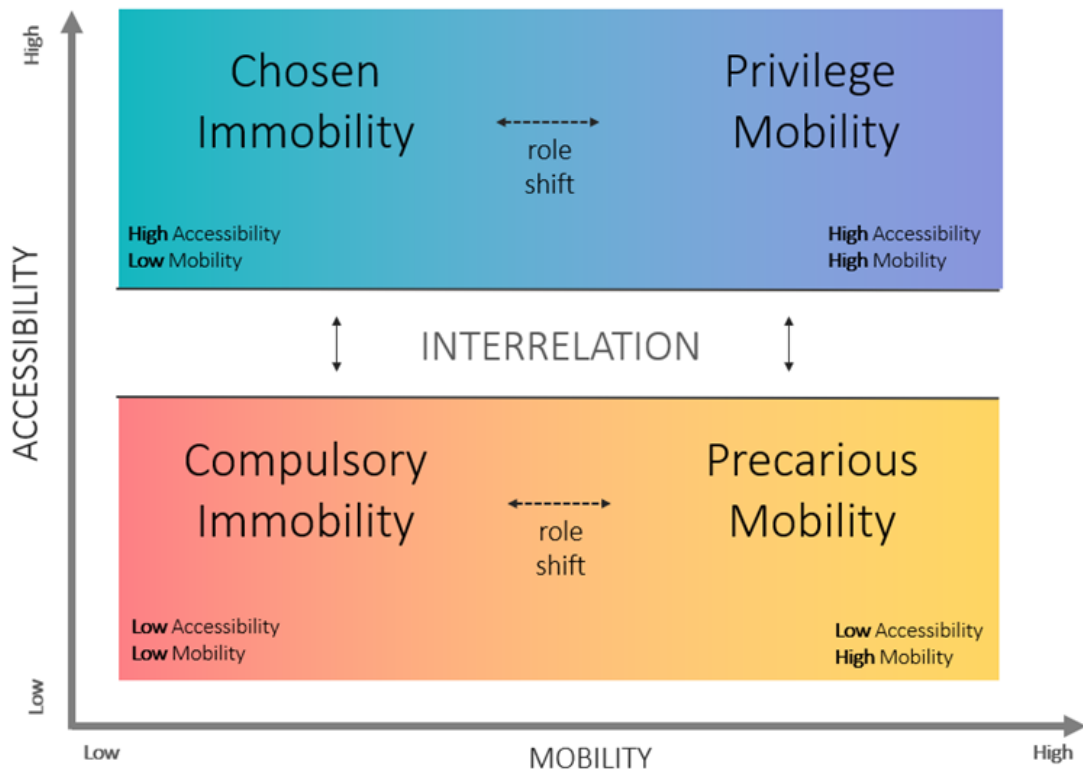


Figure 1: Mobility-accessibility juxtaposing framework to analyse interrelations among different mobility (and immobility) regimes for research on urban mobility justice

In the medium- to long-term, the degree of accessibility may vary upwards with a new transport infrastructure or subsidy policy, and downwards owing to a shortage of bus supply or income reduction. However, the degree of mobility may vary as well in the short-term and more frequently in case of ‘role shifts’ if individuals tend to move less, for instance, owing to an increase in remote working (chosen immobility) or transport barriers (compulsory immobility), especially after the COVID-19 pandemic (WEE; WITLOX, 2021). Therefore, the state of being (more or less) mobile represents a dynamic rather than a sedentary category (SHELLER, 2018b) in the framework. Within the advantageous and disadvantageous situations, commuters may alter positions across the days of the week or even during the day. The openness in the frame for ranging from more to less mobile embraces the context of ‘instability, improvisation, impermanence, uncertainty—inseparable from poverty and precariousness—[that] have always marked the lives of the majority in cities worldwide’ (CALDEIRA, 2022).

Nevertheless, overcoming the disadvantages (im)mobility may depend more on structural changes than timid improvements of the transportation system owing to the existence of solid segregation mechanisms that reduce the possibility of a role shift between the advantages and disadvantages situations. The unequal production of the city (França,

2017) and the historical allocation of resources in the transport of the middle and upper-class citizens (VASCONCELLOS, 2018) may represent relevant factors to the possibility of a shift between advantages and disadvantages.

‘Privilege mobility’ (Figure 1) could involve both private and public mobilities resources. In particular, private privilege mobility is a situation in which groups can afford a private vehicle, reside in places proximate to public goods and services, benefit from high levels of public transport supply, and travel relatively short distances but opt for driving cars to access their urban activities. We refer to this as a ‘privilege’ mobility because substantial historical and socially rooted investments, subsidies, and laws benefit this kind of mobility and offer the ‘freedom’ of movement for these predominantly white upper-class bodies. Car subsidies, free parking on public streets, road space for cars, and public investments for the construction of new roads or maintenance of pavements are examples of resource allocation acting to privilege this private mobility (VASCONCELLOS, 2018).

Although a significant portion of the ‘privilege mobility’ is executed via cars, a public-transport ‘privilege mobility’ exists as well. These circumstances occur when people avail cumulative collective benefits such as affordability, comfort, reliability, and short trips by transit to access their activities. At the first glance, it may appear contradictory to denote the term ‘privilege’ for defining this ideal case that ought to be a part of expected citizen rights and may even be universalised in certain cities of the Global North. However, in Latin American and other Global South cities, the ‘selective right’ of being (im)mobile for the upper classes and white groups may be detrimental toward the oppressed groups (im)mobilities. In the Brazilian context, Santos (1996) reported that the upper classes relish privileges instead of rights, which prevents the rights of all others, starting from the black population (SANTOS, 1996). This perspective raises questions beyond the deviation in benefits and harms of social groups and interprets their interface based on a relational perspective.

A second category in the framework related to groups experiencing high levels of accessibility, either physical or virtual, but availing low degrees of mobility, which we define as ‘chosen immobility’ (Figure 1). In this case, the upper classes opt for self-segregation in citadels (CALDEIRA, 2000), inducing the real estate market to offer closed condominiums, that “shelter all the services one (medium to high-income) family could desire”, stimulating citizens to live in bubbles of wealth, to hide from the unpleasant reality of city inequality, despite rare moments where they circulate (without much interaction) in their “armoured vehicles”. These low degrees of mobility result from the

sum of structural benefits. An extensive range of activities could be performed within these environments—from work and leisure to school for children. In principle, chosen immobility occurs when location-based activities are replaced by virtual counterparts, such as e-shopping, distance education, and online work, thereby reducing the mobility of e-commerce customers and people who perform other types of remote activities (LEVINSON; ERMAGUN, 2021). First, they experience proximity to the most collective and private urban services, representing an asset of historic public investments that were not allocated to the city’s peripheries, and therefore, may have contributed to compulsory immobility situations there. Second, the chosen immobility of the upper-class majority depends on the precarious mobility of the lower social class and oppressed races, i.e., low paid black bodies delivering food, cleaning, security, etc. Essentially, the virtual access of e-commerce and other services eliminates the travel requirement only for customers and not for the workers that serve them.

The third situation presented in the framework reflects a low degree of accessibility and mobility, which we define as ‘compulsory immobility’ (Figure 1). As such, this case was widely debated and investigated in the transport-related social exclusion (TRSE) literature in situations where the lack of transport accessibility prevents the movement of groups. Transport exclusion can be deemed as a relationship between mobility deprivation (BUTTON; NIJKAMP, 1997) and lack of social participation (LUCAS; JONES, 2012). As defined by Church et al. (2000), social exclusion represents a situation in which an individual loses ‘the ability to both literally and metaphorically connect with many of the jobs, services, and facilities that they need to participate fully in society’ (p. 197). According to Kenyon et al. (2002), mobility-related exclusion comprises the lack of adequate mobility inhibiting people ‘from participating in the economic, political, and social life of the community’ (KENYON et al., 2002, p. 211,212). Aspects such as time–space budgets of household organisation, transport systems (in terms of cost, network coverage, service quality, and personal security), and the time–space organisation of urban activities (regarding the unequal spatial distribution of opportunities, availability of facilities, and time windows of service hours) can diminish commuters’ ability to access critical activities from disadvantaged regions (CHURCH et al., 2000).

Accordingly, we refer to the situation of low accessibility and low mobility as ‘compulsory immobility’, because groups are restricted from moving owing to the precariousness or the inexistence of collective goods—both in terms of proximity to urban opportunities and the transport supply providing access to them. More importantly, the sole existence of transport infrastructure may not represent its actual availability if certain groups

cannot afford the fares or commute conditions involve severe burdens (BITTENCOURT; GIANNOTTI, 2021). Overall, the lack of accessibility and mobility is an outcome of historical and socially rooted processes involving the allocation of resources within the society, which forged the contrasting situation of the absence of collective goods in the peripheries of cities with an absolute presence in regions inhabited by upper-class groups.

Ultimately, the fourth situation forebears a low degree of accessibility with high levels of mobility, which is referred to as ‘precarious mobility’ (Figure 1). This situation is characterised by a strong paradigm in which individual start their trip in places that are identified as regions of low accessibility according to accessibility analysis. As such, this case majorly includes residents of shantytowns, who reside far from the usable transport infrastructure as well as the activities they reach. Although these specific groups encounter enormous daily-commute burdens, e.g., high fare costs, long distances, and crowding conditions, they perform these trips primarily to reach central areas, where the jobs are concentrated in the urban territory. Despite a significant portion of precarious mobility occurs through transit, it occurs through private mobility resources as well. Vasconcellos (2014) highlighted the case involving motorcycles, wherein low-income groups experienced increased accessibility and mobility at the cost of their lives owing lack of road safety, especially as an outcome of crashes with cars (mostly use by upper-classes in ‘privileged mobility’). In addition, peripheral dwellers travel longer distances and are more exposed to pollution, part of it also as a consequence of ‘privileged mobility’ by car use, which poses severe implications toward human health (BRAGA et al., 2001).

The contradiction involving long commuting duration, transit supply with lower capacity than demand for specific safety and comfort conditions, and the imminent requirement for one or more integrations to reach the destination place or activity is manifested at bodily scale but following a logic that embraces specific social groups. In particular, individuals of these groups may not be excluded from economically participating in a society owing to their employment, enrolment with public transport smart cards, or the knowledge and capability to utilize the transport system, including their own private vehicles. Overall, they might experience a degree of geographical integration with the city, but this is implemented via precarious means considering the mobility conditions in unequal Global South cities.

The framework presented integrates the concepts of accessibility and mobility constituting a ground to unveil connections between these four situations involving high and low levels of accessibility and mobility, considering both private and public mobility resources. The theoretical organization avails the notion of interrelation, which could be defined as

the moorings between advantageous and disadvantageous forms of (im)mobility. The interrelation is structural in urban transport because there is not necessarily a deliberative agent that intentionally acts to oppress certain groups aiming to sustain its own privileges; instead, is the outcome of a constellation of regulations, policies, and practices that spoliates certain groups and sustain injustices owing to various forms of oppression.

Hereinafter, we focus on the subset of high levels of mobility in the framework, considering the relationship between ‘privilege’ and ‘precarious mobility’ by public transport. The immobility situations along with the private mobility resources form a future scope of this research. In the following section, we present three relevant dimensions of transit mobility that affects mobility justice.

2.3 Mobility dimensions and its particularities upon class, race, and gender

As discussed earlier, the urban mobility-accessibility juxtaposing framework reveals various regimes of mobility and raises a debate on possible forms of extortion through commuting practices. In general, mobility interrelation is not a chaotic or random phenomenon. Instead, it follows an internal and consistent logic of massive deprivation, generally for a numeric majority, with a high concentration of resources for groups with majority power. Beyond inequality, essential oppressions exist in the daily mobility of the minority power groups, such as explicit racism, insecurity, and a lack of universal accessibility for personnel with physical disabilities. Nevertheless, to investigate and measure the outcomes of oppressive forms of commuting, we selected three relevant dimensions that are systematically exploited through transit mobility and bear critical intersections with gender, that may be tackled by the available data: income, time, and bodily integrity¹, without ignoring the existence of other oppressive forms of mobility and its extortion mechanisms.

The most measured burden in transport studies is likely the travel time. In addition, time withdrawal may result in disadvantageous forms of circulation, primarily in case they represent a significant portion of people budget of time. The time expenditure for commuting fundamentally depends on the distance of activities, transportation infrastructure, and the level of transit supply. Thus, scholars have extensively measured the

¹Bodily integrity defined by Wolfe De-shalit (2007) as ‘being able to move freely from place to place; having one’s bodily boundaries treated as sovereign, i.e. being able to be secure against assault, including sexual assault, child sexual abuse, and domestic violence; having opportunities for sexual satisfaction and for choice in matters of reproduction’ (pg. 39).

time for both accessibility and mobility. Mobility studies have measured time through surveys (BOCAREJO; OVIEDO, 2012), technologies such as smart card data (WELCH; WIDITA, 2019), and mobile phone data (ZHAO et al., 2020; RODRIGUES et al., 2021). A prior study suggests that the amount of time expended in commuting and its effects may vary distinctly across various social groups (HU, 2019).

First, the time burden yields varying outcomes based on classes. In particular, the lower classes are capital-dispossessed groups that rely mainly on job income, because they do not earn from properties and rent (PIKETTY, 2014). Therefore, the time expended in displacements reduces their potential income, either because of less available working hours (MACKIE et al., 2001) or productivity loss caused by the tiredness from long journeys to workplace (ZENOU, 2002), including the lack of time to invest in additional activities such as education. Moreover, race appears as another layer of time burden, especially in cases of racial groups segregated in disadvantaged locations (FRANÇA, 2017), where the transit provision is inferior and the major activities are situated farther in the city (BITTENCOURT; GIANNOTTI, 2021).

Gender emerges as another factor of time consumption for commuting. Female commuters are more responsible for care and perform more multi-stop trips than their male counterparts (HANSON, 2010). Moreover, they tend to travel more during off-peak periods when the transport supply is lower (LEVY, 2017). Therefore, time may be a scarce resource, specifically for this group in comparison to men, even within the same class and race. Law (1999) reported that several layers directly or indirectly constrain time resources from female commuters:

‘Gendered norms of domestic responsibility, overlaid on temporal rhythms of childcare and domestic work, and on spatial patterns of segregated land-uses, and combined with inflexible service hours and minimal public transport, generate time–space constraints that restrict the mobility of those responsible for this work (mainly, wives and mothers). Time–space constraints also take the form of gender-specific safety concerns about traveling outside daylight hours’ (LAW, 1999, p. 12).

Thus, the time constraints of female commuters result from the combination of lower access to private and public mobility resources owing to patriarchal power within households (LEVY, 2017) and multitask and care trips (JIRÓN et al., 2020), which may partially explain the reason of female commuters travelling shorter distances on average than men (MACÊDO et al., 2020). Time constraints and their effects can vary across social groups. Female commuters require more time to walk to a bus stop considering a care trip with an elderly person or children and carrying grocery bags. Moreover, the wait-

ing period perception at the bus stops can vary according to gender. Fan et al. (2016) demonstrated that female commuters' perception of waiting period at bus stops is longer owing to insecurity and fear.

The second principal aspect of urban mobility oppression involves monetary costs. Comprehensively, transit fares can render the transport system virtually unaffordable, for certain groups, and thus, deprives the users in case the fares account for a high portion of the users' income, thereby restricting them from accessing other substantive goods. In this context, transport affordability conditions were studied in terms of accessibility as the potential share of income and mobility by measuring the observed percentage income of households or individuals (BITTENCOURT; GIANNOTTI, 2021).

In the context of transit fares, various types of policy arrangements for financing public transport should be discussed—varying from integrally paid tickets to fully subsidised, but generally it is a combination of these sources. Moreover, the lack of subsidies in public transport for unequal societies may substantiate into a significant extortion of the lower classes, considering the proportion of transport expenditure to income. The universal perspective of welfare (ESPING-ANDERSEN, 1985) on transportation fare policies would ensure all citizens' access, regardless of a social group or job occupation. Accordingly, more than one hundred cities¹, including Tallinn (Estonia) and Maricá (Brazil), provide free transit fares for all users, which is maintained by other public sources. Based on conservative principles for the welfare (ESPING-ANDERSEN, 1985), selective groups can avail transport fare benefits, such as students, elderly, and formal workers, which is the case in several metropolitan regions, including London (the UK) and São Paulo (Brazil). In such an arrangement, selective groups could be targeted of fare benefits in a more progressive initiative to reduce the inequality gap if, for example, a coordinated effort integrating other public policies, encompassing education, health, and food safety with public transport subsidies, as a basis to provide a social safety net for the vulnerable population. Ultimately, certain cities have adopted market-driven policies with no subsidies for public transport, and the fares are exclusively paid by the transit users.

The third dimension oppressed through mobility is bodily integrity. Far beyond a comfort issue, crowding conditions may be related to physical integrity, considering energy consumption and stress for all users, in addition to fear and sexual harassment, especially for women (KASH, 2019) and transgenders (LUBITOW et al., 2020). Public transport crowding is a fundamental issue in metropolises worldwide (HAYWOOD et al., 2017), and female commuters experience much more violence in the public spaces of trans-

¹available on <https://freepublictransport.info/city/>

port systems compared to male commuters (LEVY, 2017). Furthermore, high levels of crowding inside vehicles and stations during peak periods (CECCATO; PAZ, 2017) tend to be more favourable environments for potential sexual assailants, because victims avail less personal space and can hardly avoid physical contact (KASH, 2019).

Although sexual assessments are frequent in public transport, few victims report occurrences to authorities (KASH, 2019). Upon considering the bureaucrats of the street (CAVALCANTI et al., 2018), Kash (2019) has identified five widespread deproblematizing beliefs of planners on sexual harassment: (i) Victims of sexual assault on transit are often mistaken or lying; (ii) Groping and sexual contact do not seriously harm victims; (iii) Victims brought the attack to themselves; (iv) Assault is natural and unchangeable; and (v) Planners should not be responsible for addressing sexual assaults, because they do not create a problem. These findings reveal the structurization of gender oppression in public spaces, where the bodily integrity of women is systematically affected by mobility conditions.

The exploitation of time, income, and bodily integrity could occur in isolation, but generally, it occurs in intersection circumstances. For instance, Kash (2019) determined that Colombian women victims of sexual harassment ‘were more than twice as likely as non-victims to avoid night travel and take more expensive modes of transportation, and 1.7 times as likely to travel in accompaniment of another person for safety’ (KASH, 2019, p. 2019). Evidently, the gender oppression of bodily integrity can increase time constraints and the monetary cost of commuting.

Overall, we briefly introduced and described three exploitable dimensions through mobility practices: time, money, and bodily integrity. In the subsequent section, we present an empirical evaluation to measure these three dimensions across class and race in São Paulo (Brazil) and investigate the possible relations among the various mobility conditions. However, future research will be required for a deeper qualification of gender, race, and class experiences that are beyond the available data adopted in the present study.

3 EMPIRICAL EVIDENCE: SÃO PAULO MOBILITY INJUSTICE

In this section we present and justify the empirical strategy, starting by introducing São Paulo through a brief trajectory of its urbanization and transport, which is relevant for discussing the results. Thereafter, we detail the data sources and the methods for measuring transit mobility exploitation of time, money, and bodily integrity across classes and races. Subsequently, we discuss the results considering gender-related aspects that comprise an additional layer of differential exploitation.

3.1 Brief trajectory of São Paulo’s urbanization and transport

Only two years after the slavery abolition in 1888¹, the population of São Paulo substantially increased, primarily owing to European immigration, from 65,000 inhabitants in 1890 to 240,000 in 1900, 580,000 in 1920, and 11.2 million in 2020 ² (IBGE). In addition to urbanization, the region has experienced rapid industrialization since the beginning of the 20th century. According to Kowarick (2019), industries employed foreigners instead of the national working class, and above all, the black population—at that moment, recently freed from slavery. In São Paulo in 1920, half of the industrial workforce comprised foreigners, and the black population was systematically immobilized in the lower social strata (KOWARICK, 2019). Rolnik (1989) reported that the racist discourse of ‘white cultural civilization for the national development’ accompanied the substitution of enslaved black groups by the free European immigrants to compose the working force.

By 2020, the metropolitan region of São Paulo housed over 20 million residents (IBGE

¹Brazil was the latest western country to abolish the slavery regime (1888 ac) and legislated at the time important institutional laws of political and economic segregation (GADELHA, 1989) that perpetuated the oppression of whites over the black population (SANTINI et al., 2021). Brazil is a paradigmatic case of a Latin America ex-colonial and ex-slavery society in which oppressive heritage prevails in the form of historic income inequality (??) and racial segregation (GONZALEZ, 1988).

²IBGE available on <<https://www.ibge.gov.br/censo2010/apps/sinopse/>>

2020). This rapid growth inhabiting 19.4 million people in a century was enabled in part by the expansion of the urban transport system, especially with the replacement of trams by buses from 1940 (KOWARICK, 2009), which increased the flexibility and capillarity of the transportation system and enabled the sprawl of the São Paulo metropolitan region through precarious regions and slum peripheralization (MARQUES, 2017). The urban frontier progression occurred through self-construction housing by the working class during off-work periods, which reduced their reproduction costs and allowed permanent wages to remain depressed (KOWARICK, 1979). Consequently, low-income, and mainly black workers started to swarm the peripheral regions where land value was lower because of the lack of access to collective facilities and services, thereby resulting in more significant social burdens. Although the peripheral regions expanded as heterogeneous spaces (MARQUES, 2017), the commonality of geographical and temporal distance from formal jobs, cultural and leisure public equipment (SIQUEIRA-GAY et al., 2019), and lack of access to public goods and services remained.

Avail spatialised information about job occupancy, income, and race of the most recent national Census of Brazilian Institute of Geography and Statistics (IBGE) surveyed in 2010 allows to identify spatial segregation of social groups housing in the city of São Paulo. The combination of those attributes following the methodology of Bittencourt et al. (2021) enables visualising for each origin–destination zone the predominant category of class and race (figure 2). A majority of the black population occupies the extreme periphery, whereas the white population remains in regions proximate to the city centre. In terms of class, most of the upper class resides in the expensive central regions, whereas the lower classes reside in the outskirts.

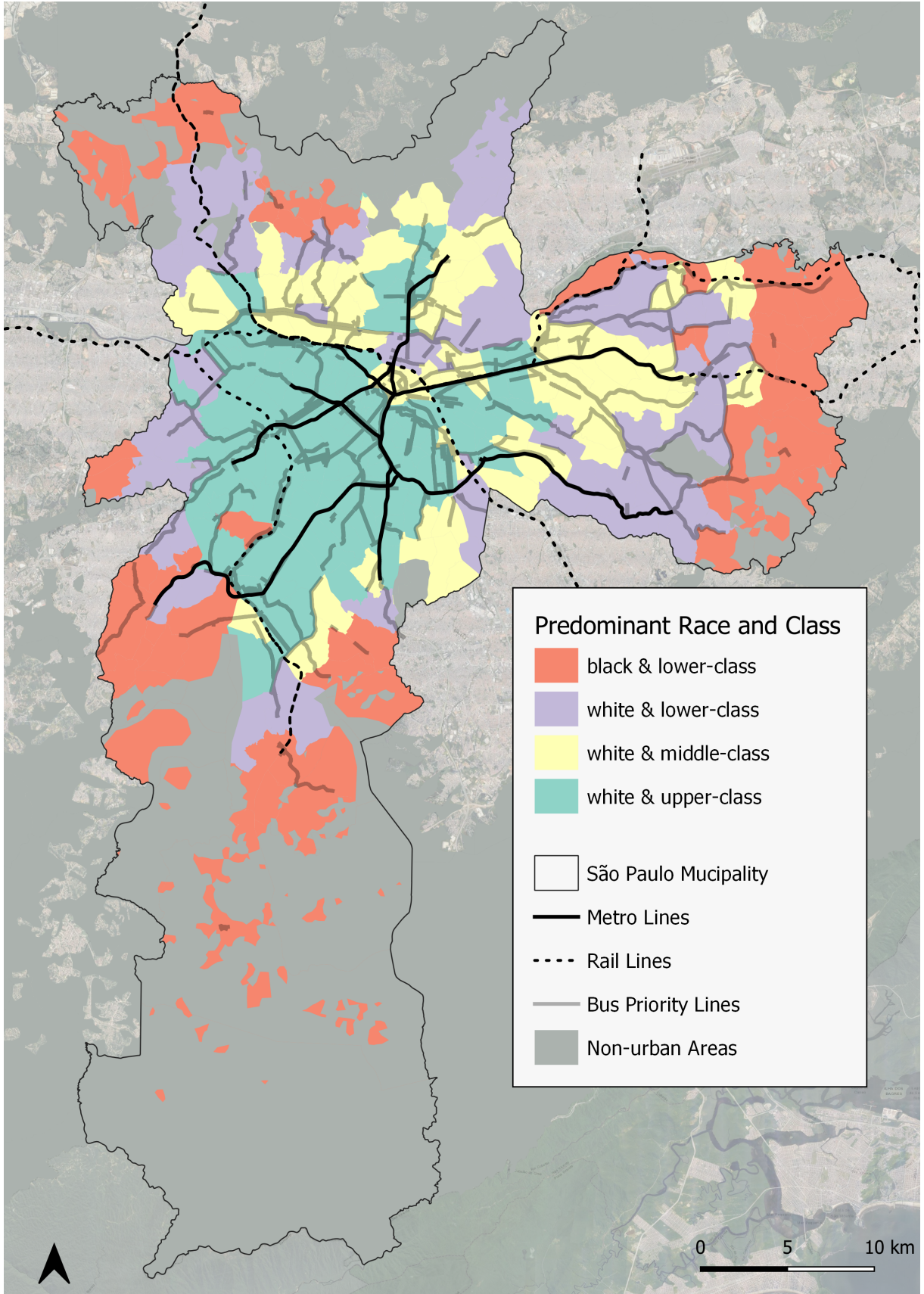


Figure 2: Race and Class Spatialization, considering the prevailing race & class for each Origin Destination zone

In addition, the prioritization of private transportation along with its guided policies forge the urban spaces and rendered public transport as materially and symbolically worse than cars (VASCONCELLOS, 2000), especially for the dwellers from peripheral regions of the city, who are majorly black. According to Vasconcellos (2018), a city designed for automobiles is a city designed for the middle-class citizen, which is primarily a white group. In symbolic and practical terms, the prioritization of the automobile (VASCONCELLOS, 2000) is a component of a broader dynamic that privileges ‘the private’ and gradually degrades ‘the public’ (KOWARICK, 2009). Owing to the lack of investment and regulation by the State, public space becomes violent, and therefore, it is avoided by the middle- and upper-classes that protect themselves in their ‘cars with closed windows and condominiums’ (KOWARICK, 2009).

Moreover, the job–residence spatial mismatch in these peripheries created tremendous pressure on the public transport system to ensure the physical connection between workers and workplaces. The São Paulo bus system bears approximately 1300 bus lines that connect 20,300 bus stops, 31 bus terminals, and a fleet of almost 14,000 buses to perform in a weekday 200,000 trips (2.7 million km per day)¹. Whereas the rail and metro systems account for 6 lines and 7 lines, respectively. According to the Metropolitan Origin Destination Survey conducted in 2017², this transit system transports more than 15,3 million passengers per day. Avail smart card data allows estimating the origin of trips by public transport from 06:00 to 7:59 (figure 3), revealing the high number of trips beginning in the peripheral regions of the city.

In São Paulo, public transport forms the principal motorised means that lower-class populations use to access activities in the city, and this is pivotal in filling gaps in segregation, because it potentially promotes spatial integration to opportunities (ANDERSON, 2010). On the other hand, peripheral public transport users face high burdens considering the long duration of displacement to access jobs, alarming crowding conditions, intense congestion, and high fares in proportion to workers’ salaries (VASCONCELLOS, 2018). Thus, urban mobility in São Paulo may have contradictory effects because it contributes toward the precarious living conditions of the lower classes through its daily burdens, regardless of providing access to urban activities and job opportunities.

¹ Available on <https://www.sptrans.com.br/>

² Available on <https://www.metro.sp.gov.br/pesquisa-od/>

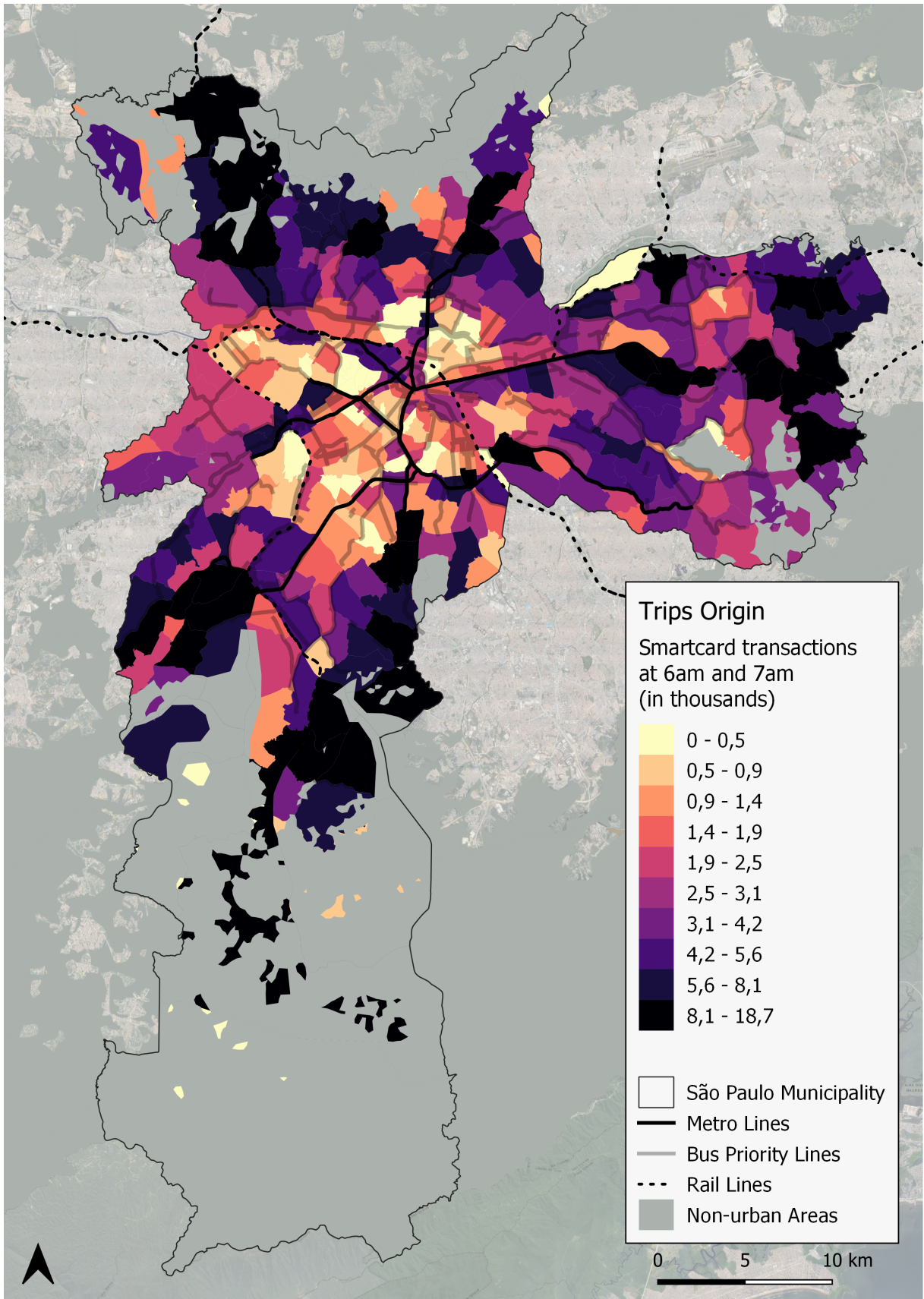


Figure 3: Public transport trips origins from 06:00 to 07:00 in the morning for each Origin Destination zone

3.2 Accessibility Analysis

The peripheries face high commute burdens—in terms of travel duration and expenditure—to access job opportunities. The time burden to access job opportunities is the outcome of the interaction between transportation and land-use, owing the concentration of employment in the centre of the city and especially the lack metro and rail network in the peripheries. In addition, the cost expenditure to access jobs can be explained by the requirement of multiple transfers between buses, rail, and metro to reach jobs associated to a fare policy that punish the need of multimodal trips.

Previous accessibility studies adopted various methods to measure job accessibility, such as the number of accessible jobs in various trip duration or the time to access various percentages of available jobs in the city. These approaches depend on the arbitrary adoption of a threshold either for time (e.g. 30,45,60 minutes) or percentage of the city’s jobs (e.g. 25%,50%, 75%) (PEREIRA, 2019). To overcome this arbitrariness we propose a novel method for defining a city’s job percentage as a threshold for measuring accessibility. The method consists in the median percentage of accessible jobs in observed travel duration by public transport from all zones (Appendix - figure 10). In other words, how many jobs need to be accessible from each zone based on its average observed commuting time (figure 4).

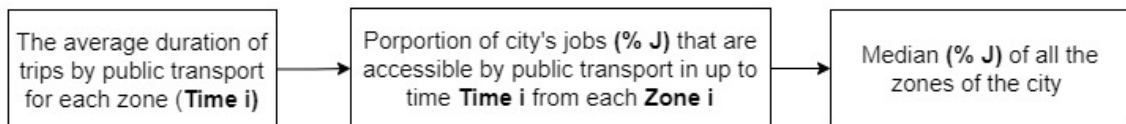


Figure 4: Threshold definition method for accessibility analysis

For the case of São Paulo, the job threshold (J) was 13%. We then compute the time and cost from each zone to access by public transport 13% of cities jobs. The results in figure 5 show that dwellers of the peripheries potentially spend a lot more time and money, specially from the east and north regions.

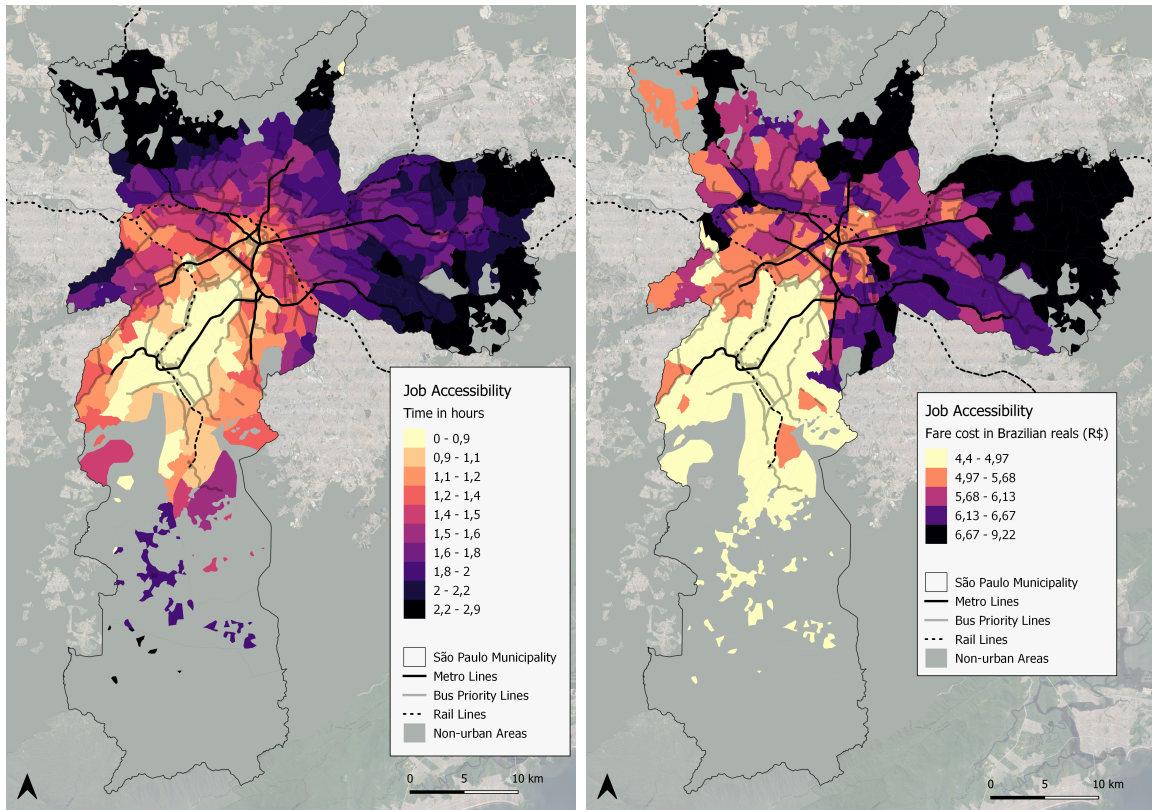


Figure 5: Job Accessibility considering only one-way trip time(left) fare expenditure(right)

The analyses of job accessibility presented so far showed an unequal spatial distribution in the city. Yet, it does not allow us to unveil mechanisms of oppression that operate at the bodily scale among social groups reproducing inequalities and urban injustices. For instance, regressive fare distortions associated with the lack of transport supply could be extorting specific social groups to the benefit of fewer. Aiming to identify such gears of extortion in mobility, emerges the methodological challenge of measuring it, from the perspective of the routes taken daily by users, the shares of social groups in the various conditions of displacement by public transport, in terms of travel time, fare cost and crowding. Following in section 3.3 is presented the data and methods for measuring the mobility indicators, as well as the results for each mobility dimension.

3.3 Mobility Analysis

We measure the three primary dimensions of mobility discussed earlier—duration, fare cost, and crowding—and provide evidence for unveiling the eventual connections between privilege and precarious mobilities by transit of various groups. The time and cost of trips were directly computed from a routing analysis using public transport Job general transit feed

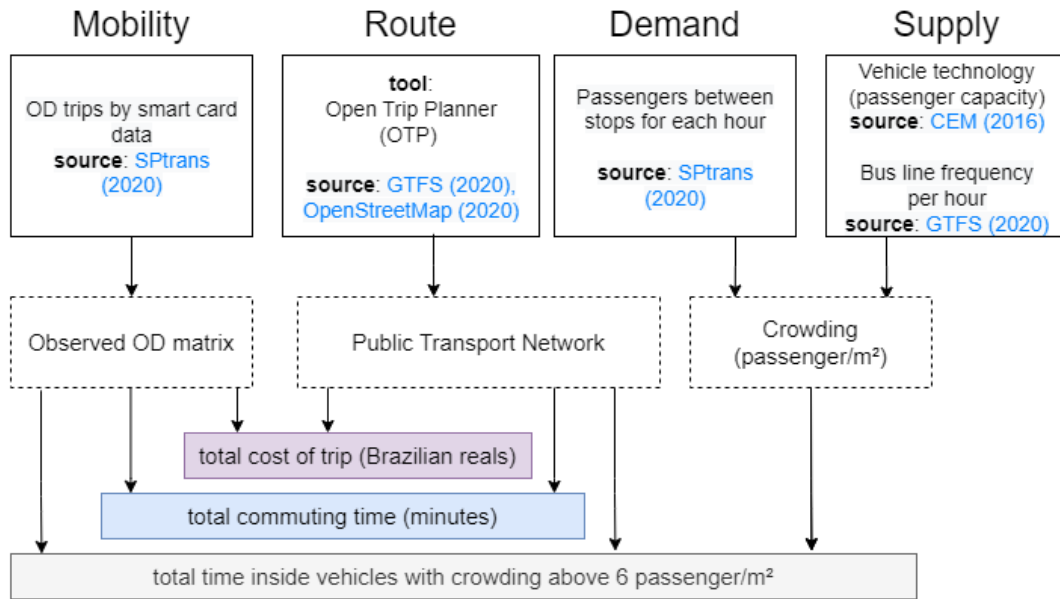


Figure 6: Data sources of mobility, demand, supply, and routing to calculate time, cost and crowding for each zone

specification (GTFS). Based on the user perspective, the approach on comfort considered time under specific crowding conditions measured in hours. We present a scheme that clarifies the data sources for the implementation of the empirical approach (figure 6).

For mobility analysis, we used the smart card data previously aggregated – for privacy reasons – in the origin and destination zones by São Paulo Public Transport Agency (SPTrans¹). This database comprises an OD matrix that counts 13 million trips of public transport (bus and rail) on a typical business day immediately prior to the COVID-19 pandemic in March 2020. The travel duration and trip costs between the zone’s sub-origins were evaluated using a transport network based on São Paulo’s GTFS and OpenStreetMap (OSM) routed via Open Trip Planner² (OTP). For each zone we randomly generated 3 sub-origins and selected the median route between the 9 (3 sub-origin x 3 sub-destination) itineraries between each zone (Appendix - figure 11). The evaluated commuting duration included the walking period to the bus stop or station, the waiting period at the bus stop, in-vehicle duration, transfers, and walking duration from the bus stop or station to the destination. The cost was determined based on the transit fares applicable in 2020, considering all transfers out of routing itineraries between the zones.

The crowding condition is a spatiotemporal sensitive variable that relies on demand and supply conditions. To obtain a high spatial and temporal resolution of the demand, we

¹SPTrans website on < <https://www.sptrans.com.br/>>

²OpenTripPlanner (OTP) is a family of open-source software projects that provide passenger information and transportation network analysis services < <https://www.opentripplanner.org/>>

utilized a dataset sourced from SPTrans that includes each bus line and time slot (hour), including the number of passengers transported in each segment between subsequent bus stops. In summary, we estimated the capacity supply for each line, time slot, and segment (between bus stops) from the GTFS hourly frequency and type of bus technology (appendix I). Based on the relationship between demand and supply for each line, hour, and bus stops, the crowding conditions of the transport network could be obtained.

After computing the transit crowding conditions, we used spatial operations to measure the duration between each OD consumed in vehicles with a passenger density greater than six passengers per square metre. According to the passenger’s perspective, this method enabled to measure the crowding conditions faced in the passenger’s itinerary. Thus, we selected to measure the amount of time above this threshold instead of the average vehicle occupancy, because any time expended beyond these conditions could represent harm in terms of comfort of the user, especially sexual harassment risk for female commuters. We computed the average travel duration, fare cost, and time under crowding conditions greater than six passengers per square meter for each zone, considering the morning peak hours from 05:00 to 06:59 and evening peak hours from 16:00 to 17:59.

For the best of authors knowledge this method to compute crowding conditions is innovative and best fit mobility injustice studies. Previously, scholars have measured crowding conditions with respect to time, evaluating the average crowding of the itinerary (WARDMAN; WHELAN, 2011; TIRACHINI et al., 2013; HAYWOOD et al., 2017). This method of measuring crowding conditions may be misleading for long-duration trips, and most parts are not crowded, because the average tends to disregard the time covered in precarious commute conditions.

To account for the time in which a user is exposed to inadequate crowding conditions, we propose a novel approach to measure the crowding conditions according to the time covered under inadequate conditions, considering the threshold of six passengers per square meter, which is the crowding limit set by the Brazilian National Standards Organization (ABNT) in the Transport—Technical specification for manufacturing vehicles of urban characteristics for the public transport of passengers (NBR 15570:2009). This threshold may be deemed as high in certain contexts; for instance, in London, Transport For London (TFL) has recently adopted the threshold of four passengers per square meter¹. More importantly, the literature suggests that the perception of crowdedness may vary across different contexts (LI; HENSHER, 2013).

¹Available on <<https://content.tfl.gov.uk/travel-in-london-report-14.pdf>>

The smart card data available for this study did not account for gender characteristics. Regardless, the approach involving smart card data aggregated in zones fails to capture the gendered aspects of mobility, because this dataset does not facilitate the identification of care trips and multiple trips conducted by female commuters during walking. Nevertheless, we can relate the findings presented in the following section to the gendered aspects of mobility discussed in theoretical portion of this study. Thereafter, we present the results of the indicators and analysis for travel time, cost, and crowding conditions.

3.3.1 Travel time

The commuting duration by transit is distinctly unequal and follows the logic of favouring the white upper class, and it is onerous for the black and lower classes. The following chart (figure 7) represents the average time expended per zone, considering trips during the morning and evening peaks. It comprises the estimation of commuting period considering a trip from the origin at the morning peak (from 05:00 to 06:59) and the returning trip at the evening peak hour (from 17:00 to 18:59).

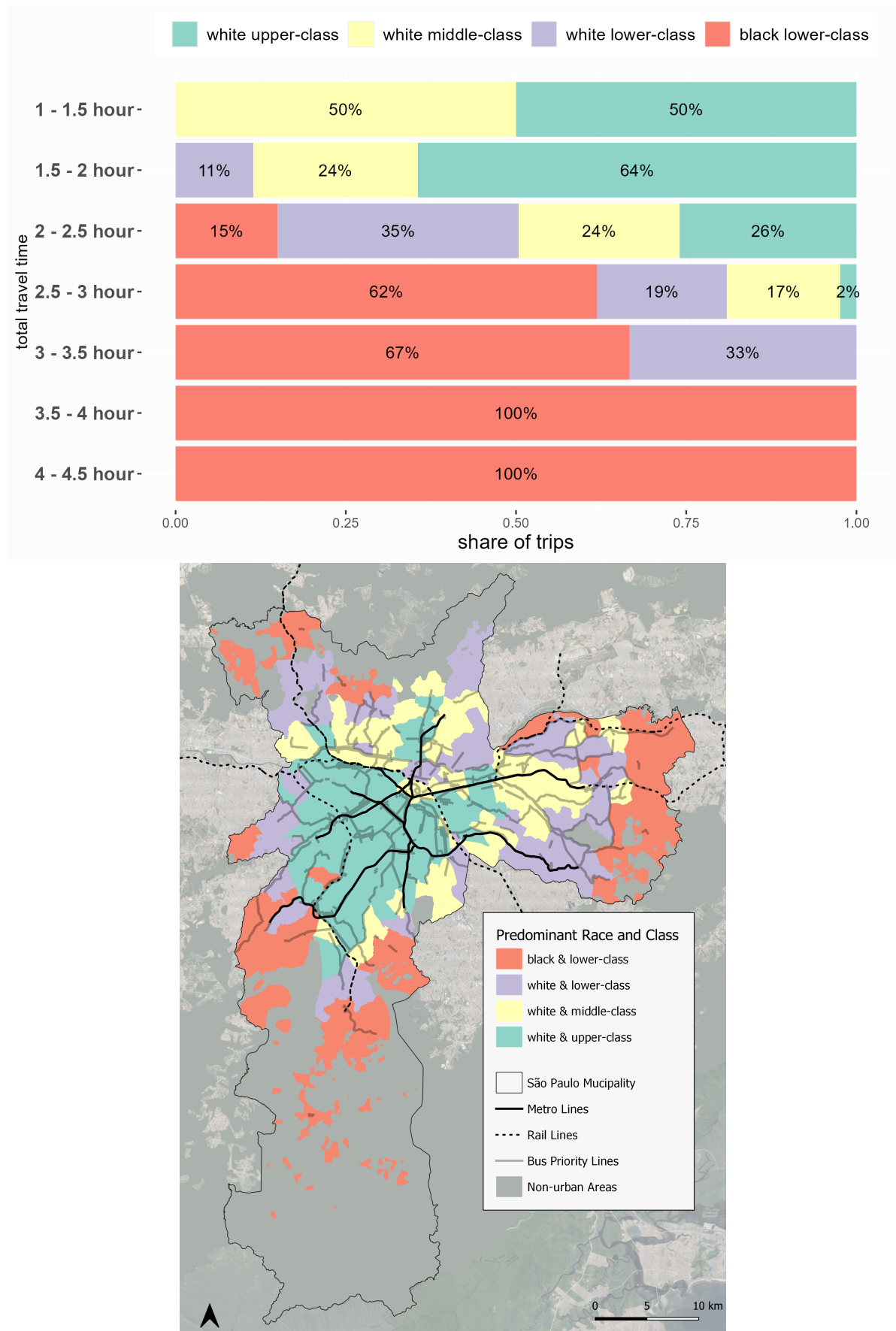


Figure 7: Travel Time (morning + evening peak hour) considering race & class (left) and spatialization of race & class (right)

In figure 7, y-axis ranges charts from 1–1.5 hour at the top to 4–4.5 hour at the bottom, with variations of 1.5 hour in each interval, whereas x-axis represents the percentage of the class and race category composing the respective time range. The chart reveals important findings. First, public transport is efficient for several central zones with an average travel duration of less than 2 h, as represented in the first two horizontal bars of the chart (figure 7). Second, among the zones with the lowest commute duration (< 1.5 hour), more than 50% are majority upper-class zones and 100% belong to majority white zones. As observed in the third range, the proportion of the upper-class diminished to 26% and that of the lower-classes increased to 50% thereby revealing comprehensively inverse relationship between the presence of elite groups and the travel duration. The lowest average commuting duration for a majority-black zone ranges within 2 hours to 2.5 hours, in which the presence of majority upper-class and white zones is less than 26%. Third, the analysis indicates an average commuting duration greater than 3 hours with 100% zones pertaining to the majority lower-class zones, thereby revealing the privilege of selective groups in travelling shorter distances and its relation to their income. Fourth, the high presence of the majority of black and lower-class zones is evident in ranges (3 hour to 4.5 hours) from two to three times the commuting times of the first range (1 to 1.5 hours). Ultimately, we observed that 100% of the zones in the ultimate range, from 3.5 to 4.5 hours, were occupied by majorly lower-class and black individuals.

The variations in commuting duration between groups may explain the reason of low-income residents from the precarious settlements in São Paulo starting their first trip before the better-off group (PIERONI et al., 2021), thereby indicating the time resources withdrawn daily from the black and lower classes. At the city scale, the exploitation of time in São Paulo overlaps with the precariousness or inexistence of other collective goods such as public sewage systems and garbage collection (SLOVIC et al., 2019), constituting multiple urban deprivations to the most disadvantaged populations. At the national level, according to the National Geographic and Statistic Institute (IBGE, 2019), 17.9% of the black population does not have access to garbage collection (against 6% of white), 17.9% cannot avail public water supply (against 11.5% of white), and 42.8% does not have access to public sewage systems (against 26.5% of white)¹. These statistics signified that the black population hardly experienced the appropriation of urban benefits.

In an urban environment oppressive towards the black population, the waste of time in compulsory commuting represents an additional layer of scarcity or the absence of col-

¹Desigualdades Sociais por Cor ou Raça no Brasil - Brasil available on <https://biblioteca.ibge.gov.br/visualizacao/livros/liv101681_informativo.pdf>

lective goods. These can be illustrated by how high-capacity public transport systems were planned and implemented within the city of São Paulo. Although peripheries embrace most of the public transport dependent population, historically the metro stations were settled in upper-class and white areas. By the year of 2020, 83 white upper-classes zones, 34 white & medium-class zones, and 18 white & lower-classes zones accounted for a metro station in up to 500m. On the other hand, only 4 black & lower classes zones accounted for metro stations in up to 500m (Appendix - figure 13). This inequality recalls for an interrelation, since the priority for upper classes and white implied in a historical project of leaving behind lower classes, but especially the black population.

3.3.2 Fare cost

Analogously, we measured the average zone expenditure on public transport considering the observed trips from the origin during the morning peak hours (05:00 to 06:59) and the return trip at the evening peak hours (17:00 to 18:59). This study considered the fares prevailing in the year 2020: R\$ 4.40 (US\$ 1.10¹) for only bus, metro, or rail, R\$ 7.65 (US\$ 1.903) for the combination of bus and rail or metro, and R\$ 12.05 (US\$ 3.003) for bus, metro, and rail, all considering the transfer duration of 3 hour in the Bilhete Único (smart card data). The chart (figure 8) plots the y-axis in ascending ranges from R\$ 6–9 at the top to R\$ 18–21 at the bottom, varying by R\$ 3 at each interval, whereas the x-axis represents the percentage of the class and race category composing the respective cost range.

The chart in figure 8 indicates a pattern in which the majority white and upper classes bear lower commuting costs, and a relative rise of the lower and black zones share as the price range increases. This pattern signifies that public transport fare policy enable the residents of the central regions to spend considerably less money to transit around the city, whereas the lower classes and the black population face higher costs for mobility. Among the first range price of R\$ 6–9, 100% of trips belong to majority upper-class and white zones. At the highest cost average R\$ 18-21, 100% of the zones are majority black or lower class.

¹In January 1st of 2020 the exchange rate was 4,0180 BRL = 1 US\$.

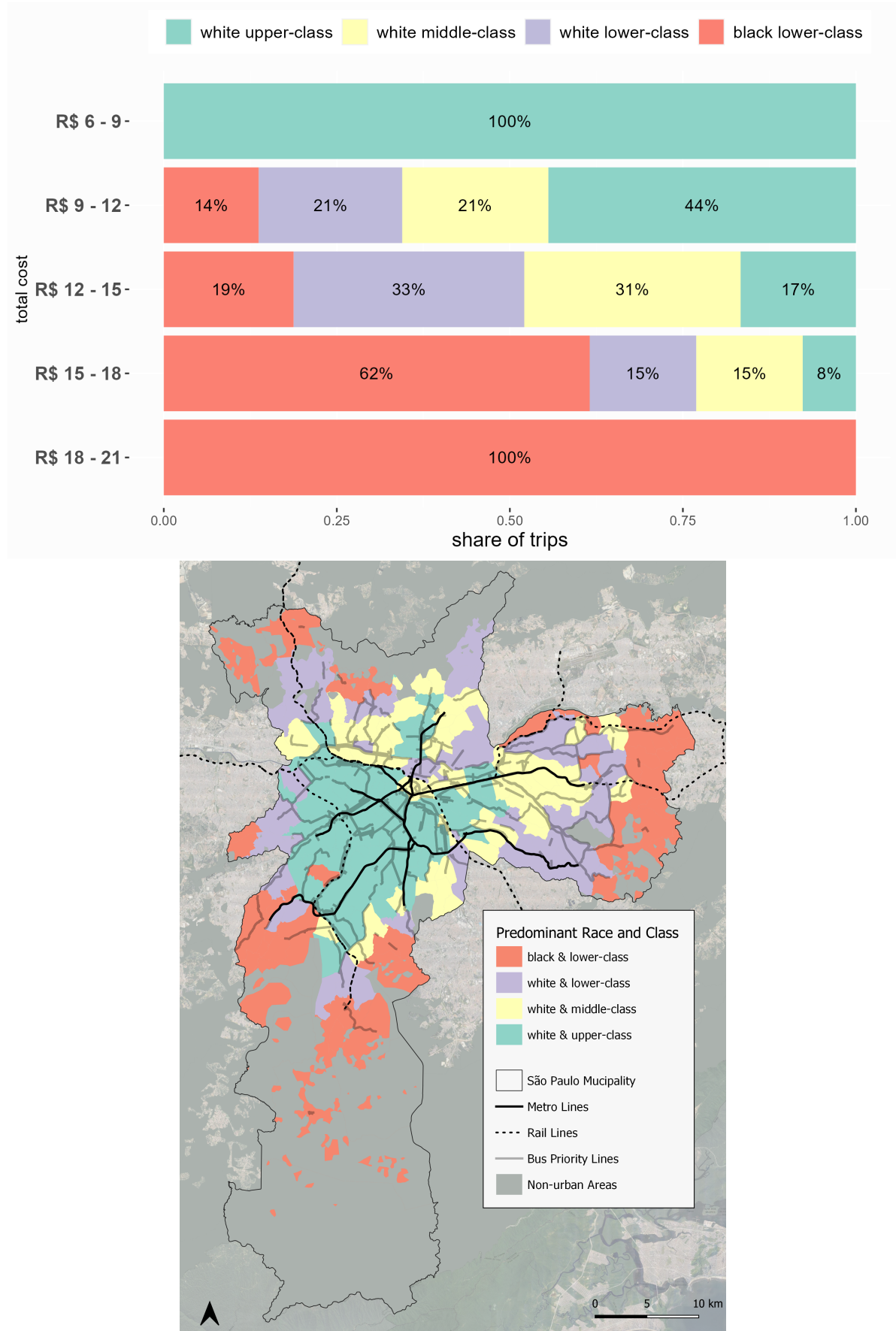


Figure 8: Cost (morning + evening peak hour) considering race & class (left) and spatialization of race & class (right)

The literature has already considered the relative cost of public transport fares to household income (SEREBRISKY et al., 2009; VENTER, 2011; GANDELMAN et al., 2019), for instance, the lower classes pay relatively more for being mobile than the upper classes. However, the above-mentioned findings reveal that the lower classes and black not only pay relatively more to use the public transport, but also, they pay more in absolute terms.

Although the above analysis comprised only race and class categories, essential aspects related to gender can be considered as well. According to the 2017 OD Survey from Metro Company, the average income of women in São Paulo was 31.58% lower than that of men, who are more than two times likely to drive a car, if the family owns a single vehicle. Incidentally, the public transport share of men and women is similar (48,2% and 53,7%, respectively) if the household owns no cars. However, for households with a single vehicle, the transit share for men plummeted to 30.6%, whereas that of women remained higher (41.8%). The public transport share between men and women converges once more only if the family holds two cars (20.5% and 24.3%), implying the gendered power relations within the household that benefit men (Appendix - figure 14).

Thus, the exploitation through public transport fares may affect more intensively for women. Furthermore, oppression may achieve the highest levels at the intersection of women, lower class, and black, because this group is unequally concentrated in particular low-paid jobs in the labour market of Brazil (REZENDE; LIMA, 2004).

3.3.3 Crowding

Crowding conditions were measured further in terms of the zonal average time consumption inside a public transport vehicle based on the trips observed from the origin during the morning peak hours (05:00 to 06:59) and the return trip during the evening peak hours (17:00 to 18:59). For this analysis, we considered the crowding conditions of all bus, rail, and metro lines, as detailed in the section 3.

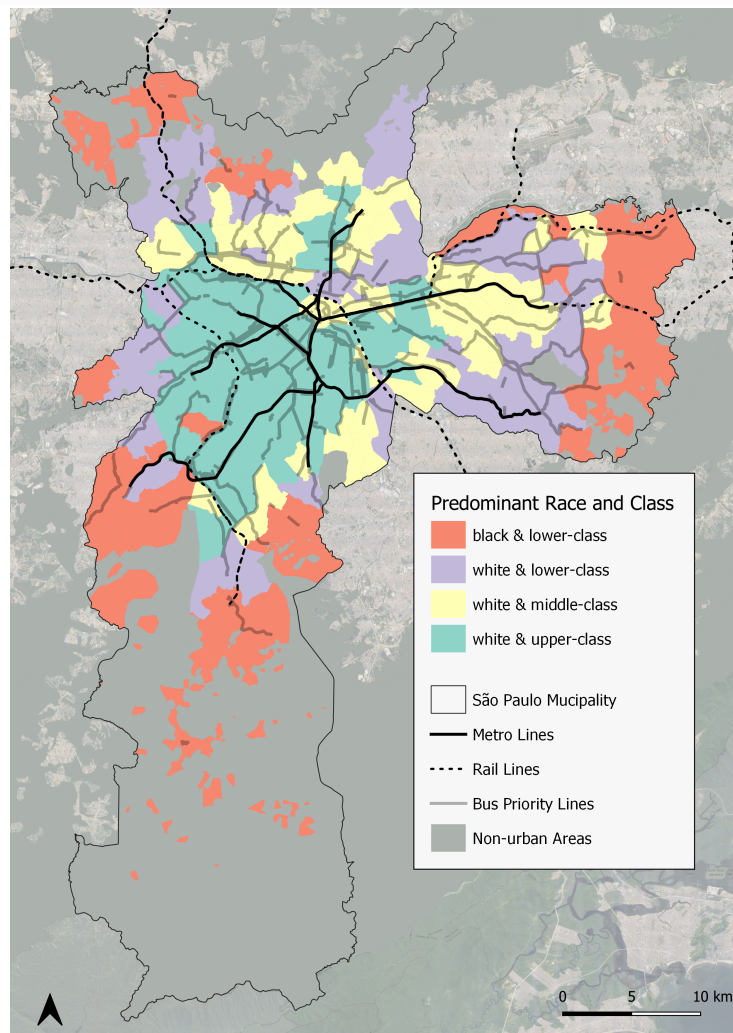
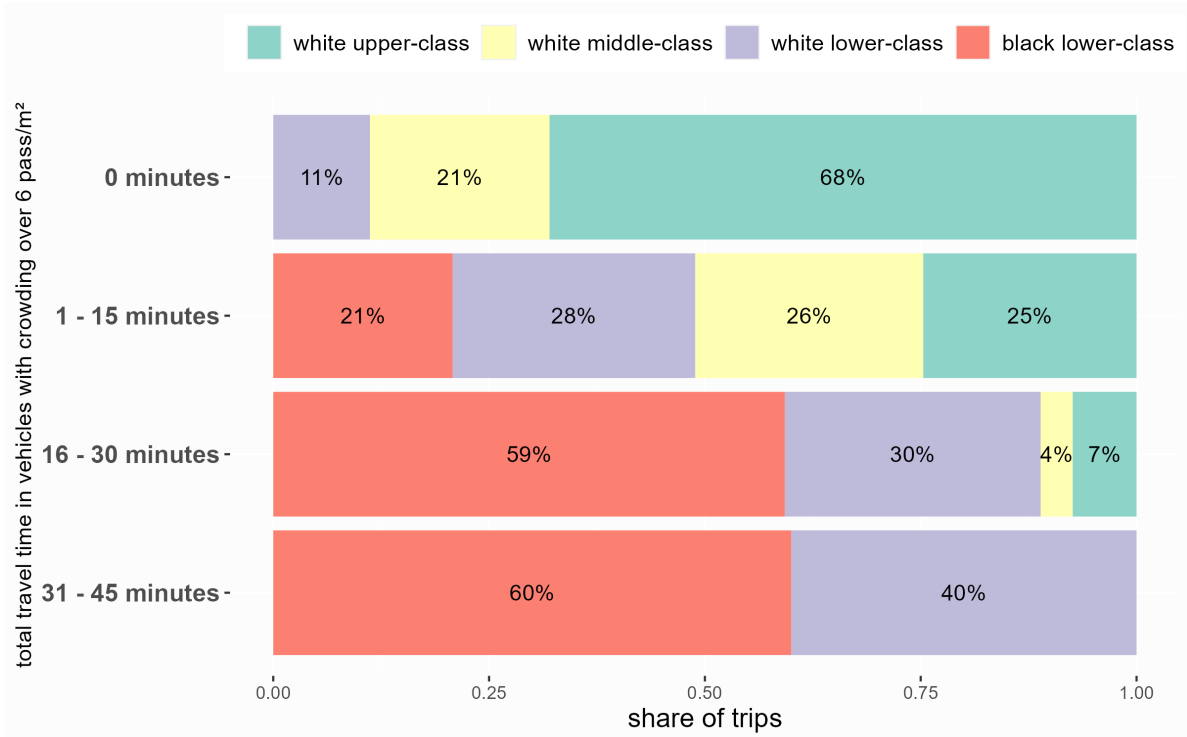


Figure 9: Crowding (Time under crowding above 6 passenger/m² (morning + evening peak hour) considering race & class (left) and spatialization of race class (right)

In the chart portraying the crowding conditions (figure 9), the y-axis denotes ascending ranges from 0 min at the top to 31–45 min at the bottom, varying by 15 min at each interval, whereas the x-axis represents the percentage of the class and race category composing the respective time range. In the first range of 0 minutes inside vehicles with crowding condition of more than six passengers per square meter, over 100% of the zones were majorly white and more than 89% were middle- or upper-class citizens. As the time under inadequate crowding conditions increased, the presence of white and upper-classes gradually diminished, whereas that of lower classes and black citizens increased. Remarkably, about 60% worst ranges of 16–30 and 31–45 min are black, which evidences a notable difference in the commuting conditions for white and black within the same city.

This analysis revealed values that were much lower than the average total time. Nevertheless, the in-vehicle duration under high levels of crowding significantly affects the user experience, increases stress, fear, and the possibility of a harassment. Although precarious mobility can affect bodily integrity of all genders, female commuters are specifically affected by this kind of oppression. A recent survey conducted in 2021 on 425 women in São Paulo by the Rede Nossa São Paulo Institute reported that 52% of women perceive public transport as the riskiest place for sexual harassment¹. The same survey indicated that 47% of the 425 women interviewed had already suffered sexual harassment while availing public transport. Therefore, crowding appears as a relevant aspect of violence related to gender oppression in public spaces.

Comprehensively, the three dimensions exploited through mobility are discussed individually, but they overlap in practical conditions. Overall, the upper white classes access affordable transits and require a short commute duration under adequate conditions of comfort, typically seated in the vehicles during daily journeys. In contrast, the black and lower classes expend considerably more—both in absolute and relative terms—to access mobility by transit, cover an increased duration in commute under inappropriate conditions that put their bodies at risk of harassment. This reflection is not merely an inequality phenomenon, but an interrelated mobility regimes of various social groups commuting in the city. The fare rules benefit commuters who do not require to transfer between bus, metro, and rail lines, who are primarily constituted of dwellers with higher incomes and majority-white zones, to the detriment of the black and lower classes.

In principle, the commuting duration is an outcome of spatial inequalities and the concentration of economic and social opportunities in high-income regions. This urban

¹available on <<https://www.nossasaopaulo.org.br/wp-content/uploads/2021/03/ViverEmSP-Mulher-2021-apresentacao.pdf>>

and social structure extracted from the lower classes' valuable dimensions for well-being. As the metro system in São Paulo lies mostly in the white zones, the black bodies are to a large extent excluded from this high-capacity and faster transit system. The allocation of public and private mobility resources to the upper classes reveals an intrinsic relationship to the lack of transport infrastructure in the peripheral regions of the city.

Furthermore, the logic of exploitation through mobility appears in the broader context of oppression, as revealed by the general national statistics of Brazil for race. According to the National Geographic and Statistic Institute (IBGE), the country accounts for approximately 214 million inhabitants, among which the majority are black (54%). The black population is more excluded from education as the alphabetic rate of black (9.1%) is more than twice that of the white (3.9%). Moreover, the black bodies constitute the minority in political representation in congress, where the proportion of white (75.6%) is three times that of the black (24.4%). As another layer of urban violence, the bodily integrity of black citizens is violated in urban mobility owing to the long and crowded commuting. The homicide rate was three times higher for black (98.5 per 100 thousand) compared to that of white (34 per 100 thousand), and 66,7% of the incarcerated population is black – a form of compulsory immobility. These numbers reflect the Brazilian heritage of slavery and colonial societies that historically discriminated the black population from participating in political and power arenas. The mobility aspects that were empirically evaluated in this study illuminates the consequences of racist structures as well as the eventualities of their reproduction.

4 CONCLUSIONS

Mobility justice is a meaningful approach for reflection on how people move within the cities. Whereas accessibility analysis accounts for the interplay between land use and transport at the urban scale (GEURS; WEE, 2004), mobility analysis enables the understanding of movement at the bodily scale. There are important effects of relations between social groups regarding gender, race and class transpiring in commute that cannot be captured by accessibility. For instance, when considering gender, there are barely the same share of men and women settle in the urban territory, herein the spatial inequality analysis alone does not help to find distinctions for the perspective of gender. On the other hand, the mobility analysis conducted in this study was sensible to gender aspects by capturing the crowding conditions in revealed commutes that have oppressive effects especially for women owing sexual harassment (KASH, 2019).

This research aimed not to discredit the distributive justice approach applied on transport but to trigger a debate based on the perspective of a relational approach for mobility and transport. We argue that the understanding of justice, especially from cities of the Global South, must account for the oppressive relations between social groups, instead of only looking at distributions among individuals. Accordingly, we proposed a generalizable new mobility-accessibility juxtaposing framework that distinguish various mobility regimes of advantageous ('chosen immobility' and 'privilege mobility') and disadvantageous ('compulsory immobility' and 'precarious mobility'). The proposed frame constitutes a ground for operationalizing concepts of mobility justice for urban research by enabling the reflection on the possible interrelations, connections, and interdependencies between these various urban (im)mobility regimes to identify current injustice. The theoretical proposition raises a relevant perspective for both qualitative and quantitative studies regarding urban transport and mobility.

We performed an empirical evaluation from a Global South city that measured three central dimensions of mobility (time duration, fare cost, and crowding) for various races and classes. Considering time duration of trips, we found that all the zones are majority

white in advantageous mobility situations (from 1h to 2h), whereas in the disadvantageous (above 3h30), all the zones are majority black. Regarding cost, all the zones are majority white in advantageous mobility fares (below 9 Brazilian reals), whereas in the disadvantageous (above 18 Brazilian reals), all the zones are majority black. Finally, we adopted a novel approach to estimate the crowding conditions from the user's perspective considering the commuting duration under a minimum threshold. This analysis reveals that situations of no overcrowd (below 6 passenger/m²) is faced only by majority white zones, whereas above 30 minutes in overcrowd vehicles is only faced by majority lower class zones.

The presented findings suggest that race and class inform to a large extent the mobility regimes by public transport today in the city of São Paulo. The meaning of the coexistence of uneven mobility regimes can be in part explained by historical and structural oppressions between white and black, upper-class, and lower-class. For time and crowding, we can reflect on the systematic forms in which the lack and precariousness of transport supply and infrastructure for mainly majority black zones historically transferred resources to sustain the privilege white zones. When it comes to fare cost however, we unveil an unjust regressive subsidy. *Ceteris paribus*, black bodies pay more to be mobile than they would if the white paid the same as the black, revealing an interdependent relation in which black and lower classes non-reciprocally sustain low mobility cost by public transport for white and upper classes.

The social and urban structures have effects on commuting time of different races and classes, pointing towards a historical connection between the existence of advantageous and disadvantageous mobility regimes. Unlike addressing spatial inequalities increasing accessibility in mid to long-term changes in land use and transport, this study unveils two oppression-generation mechanisms that could be addressed in the short to medium term, since it is related to fare policy and bus system supply. First is the regressive fare policy that spoliates the poorest groups for the benefit of the upper classes. Second, the gap between supply and demand for lower classes and black that has violent effects on their bodily integrity through the crowding conditions. These findings suggest that mobility analysis is relevant to be considered for the implementation of policies and practices aiming to combat urban injustice.

The empirical results unveil the existence of a social hierarchy (SHELLER, 2018a) in the urban structure and transport system in an urban LA context. São Paulo's urban mobility seems to be defined, rather than deformed, by the interrelated existence of advantageous and disadvantageous modes of (im)mobilities. The findings reveal a remarkable

presence of racialized and gendered colonial histories in the current urban mobility conditions by public transport. On account of this context, it seems flimsy to sustain the debate of justice without considering social groups and the oppressions between them. We argue that the debate on urban mobility justice must account for the historical oppressions and the origins of the current inequality levels.

This research has the limitation of not considering commutes for the metropolitan region of São Paulo, which likely implies underestimating commute burdens owing to the lack of integration in transport system for intermunicipal trips. Due to the lack of information on race and class in the smart card database, this study also had to use a zone aggregate information and combined it with the 2010 census information, which is the latest national census when this research was conducted, what implies in possible imprecisions due to, for example, ecological fallacy. Since the trips were aggregated for each zone, we were not able to track the trips for each user, instead we adopted the trips in the morning and evening peak hours to account for averages times, cost and crowding for each zone. A future study adopting each smart card user as analysis unit, enriched by social economic, and race will be welcome for a more accurate result.

Although this study did not discuss the organisation of power and institutions, it provoked a sociological reflection on mobility based on the concept of relations between social groups and presented evidence of extortions operating through urban mobility to sustain the structural forms of oppression of lower and black groups. In future research, we look forward to identifying and measure the causal effects between the various urban mobility regimes. Furthermore, the decision-making process of investments, public subsidies, and the cumulative benefits and harms subjected to various social groups over time. Young (1990) claims political and cultural movement based on the consciousness of oppressive systems, both for the disadvantaged and privileged groups. One of the aims of this study is to highlight the mobility oppressions acting between classes, races, and gender for the understanding of current injustices.

This research focus on urban mobility injustice and not straightforward addressed climate issues, nevertheless the scope of the study is public transport, a sustainable way of circulation within the cities. In a planetary scale, the crisis of social and economic inequality is interrelated to climate change mitigation and adaptation¹. In São Paulo, the transportation sector is the main opportunity to reduce more than 60% of CO² emissions

¹By 2030, the richest 1% have per capita consumption emissions forecast 30 times higher than the global per capita level compatible with the 1.5°C goal of the Paris Agreement, whereas the poorest half population of the world are set to remain several times below that level (Institute for European Environmental Policy - OXFAM, 2020)

by 2050, through low-carbon transition and modal change in transportation (MUNICIPALITY, 2020). At the urban and bodily scale, the challenges of mobility and climate injustice must be urgently addressed in a combined effort towards improving public transport, making it more affordable, accessible, sustainable, and just.

5 APPENDIX

I. The threshold to calculate the job accessibility was obtained as following:

a. Calculated the average time of users departing in the morning peak (6h00 to 7h59) for each zone. b. Measured the percentage of the city's jobs (obtained in the 2017 Metro Survey) that could be accessed by public transport in the average time (obtained in the previous step 'a') for each zone. Which is represented in the following chart:

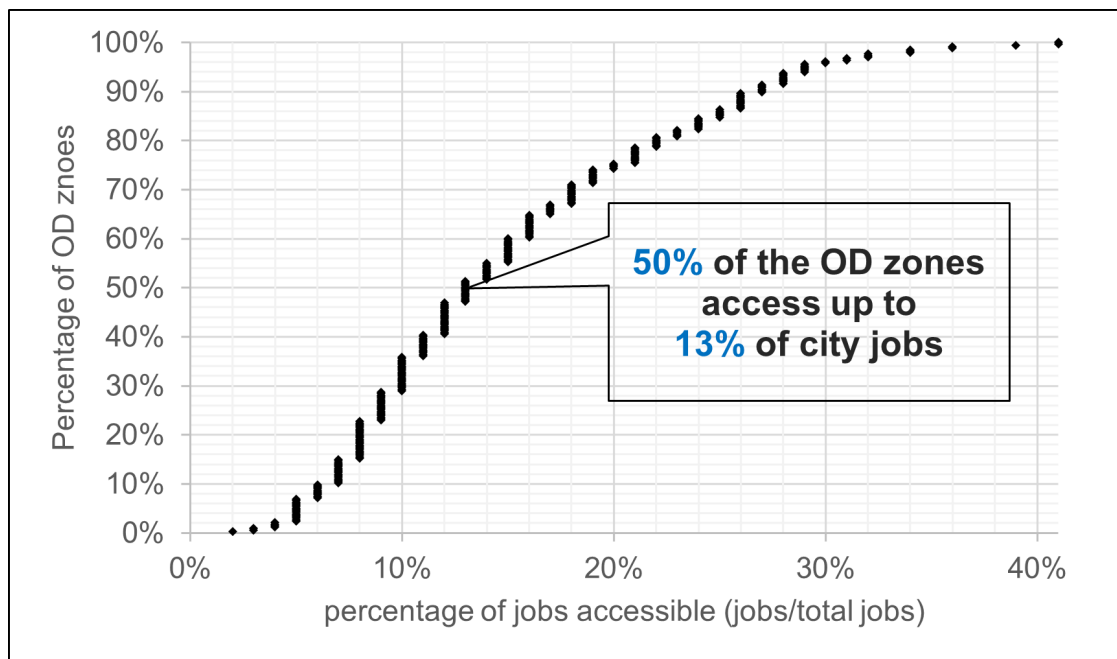


Figure 10: Accessibility threshold

Source: Metro Origin Destination Survey (2017)

c. The median value (50% of the zones) corresponds to 13% of all jobs accessible by public transport.

After that we measured the time and cost by public transport to access 13% of the city's jobs from each OD zone. The results were presented in Figure 3 - Job Accessibility time (left) and fare expenditure (right), considering only one-way trip.

II. Sub-origin (and sub-destination) for each. These sub locations were randomly generated and we select the median itinerary between each OD pair. For instance, from zona A (p1,p2,p3) to B (p1,p2,p3), there are 9 pairs (Ap1 – Bp1, Ap1 – Bp2, Ap1 – Bp3, Ap2 – Bp1, Ap2 – Bp2, Ap2 – Bp3, Ap3 – Bp1, Ap3 – Bp2, Ap3 – Bp3). We calculated all the 9 routes and selected the median in time to compute the pair OD between zone A and Zone B.

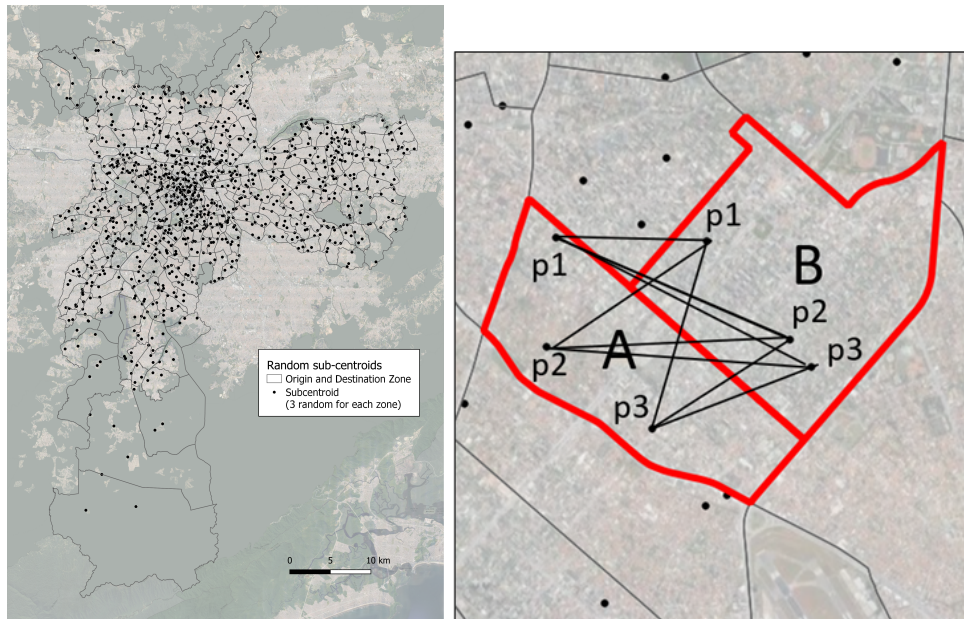


Figure 11: Origin Destination pair between zones

III. Bus technology, standing area and seats for estimating capacity to calculate the average crowding condition.









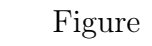
Bus Technology Figure (not in scale)	Bus Technology	Standing Area [m ²]	Seats
	Articulado	12,94	38
	Articulado (23 m)	19,32	55
	Básico	6,64	35
	Biarticulado	23,19	55
	MicroBus	2,90	21
	Midiônibus	4,70	25
	Miniônibus	3,41	21
	Padron (13 m)	8,41	34
	Padron (15 m)	10,72	37

Figure 12: Bus types and capacity

IV. Metro station overlay with spatialized race & class.

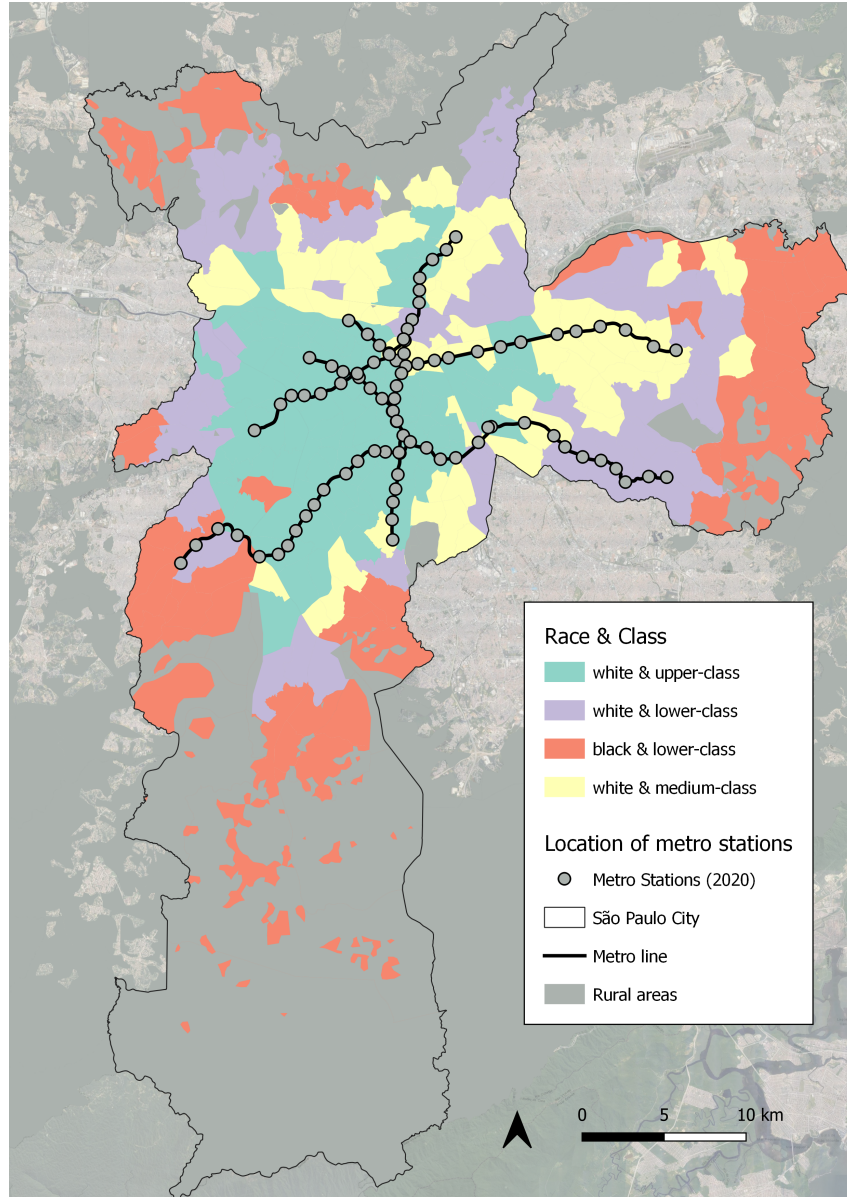


Figure 13: Metro station and class& race

V. Driving car in the household.

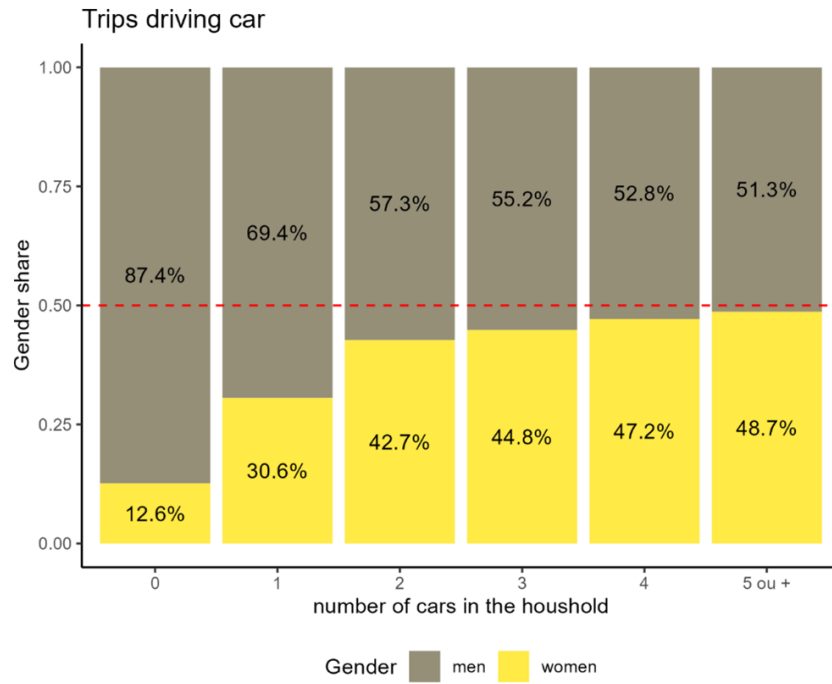


Figure 14: Trips driving car considering gender

Source: 2017 OD Metro Survey.

VI. Charts of time, cost and crowding adopting quantil intervals

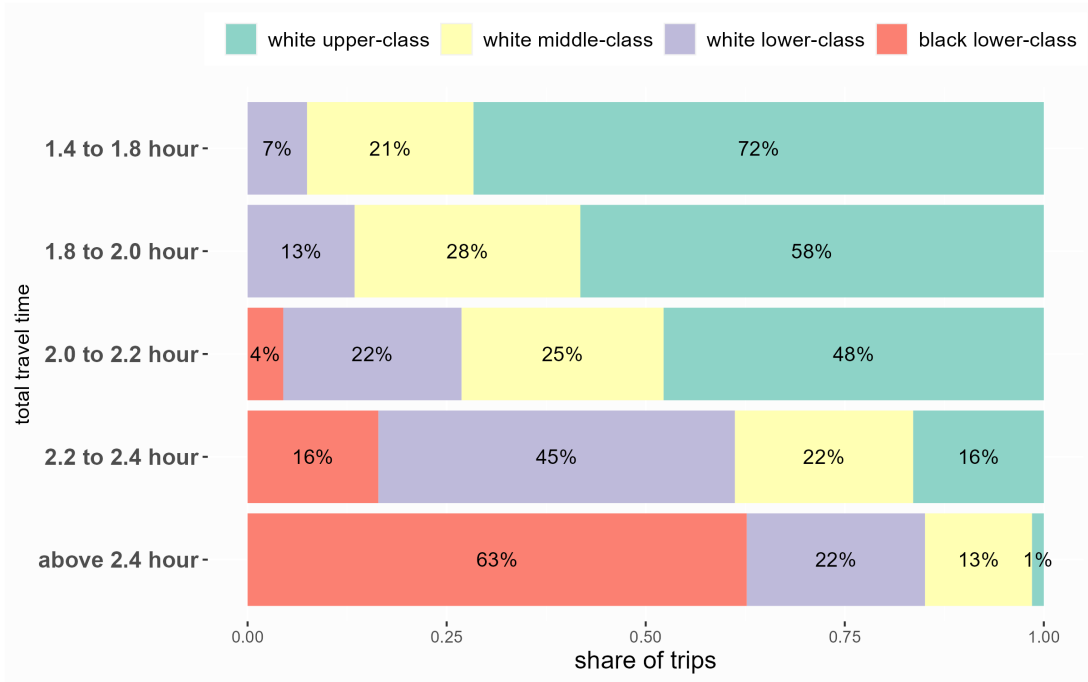


Figure 15: Time in quintile breaks

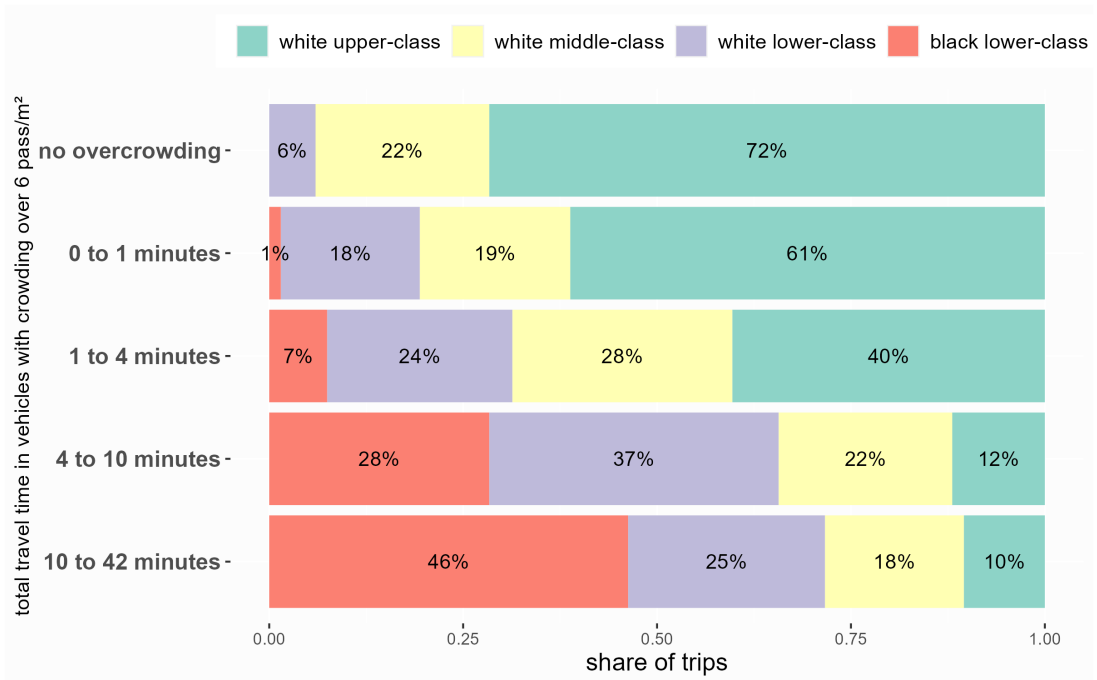


Figure 16: Crowding in quintile breaks

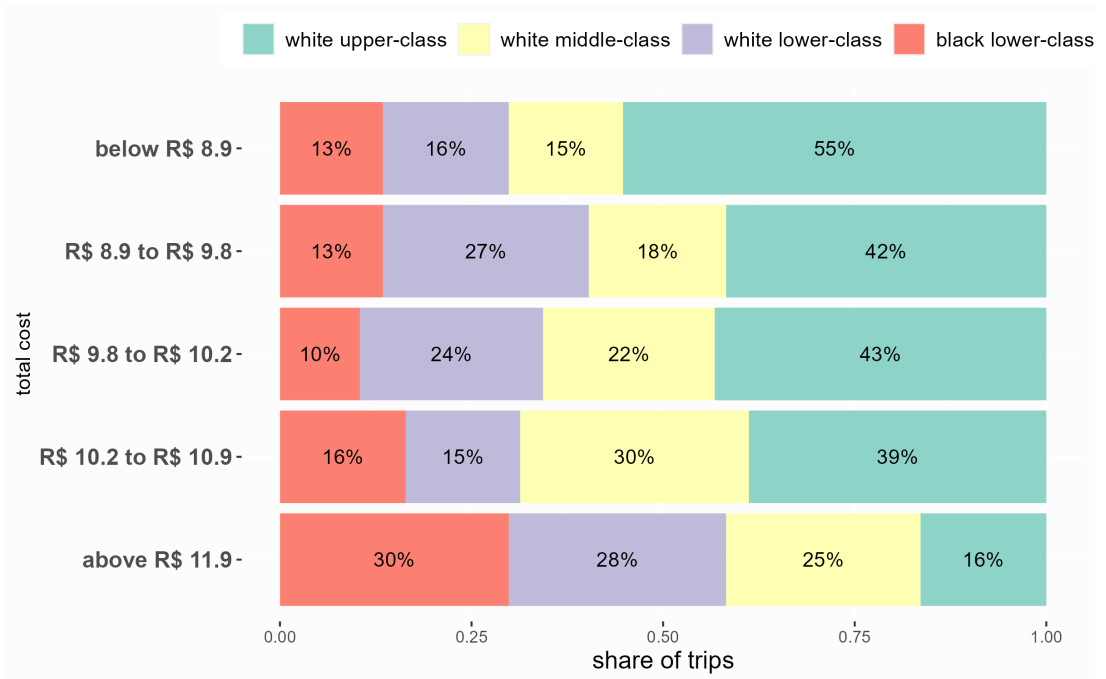


Figure 17: Cost in quintile breaks

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