**Bicycle and Equity: exploring the distributive impacts of bicycle-related benefits**

**Abstract:** Encouraged by the sustainable development goals, cities around the world are defining planning strategies to promote the bicycle as a suitable and accessible transportation option. Yet, despite the political efforts to change the current car-oriented paradigm, it remains overlooked to what extent issues of equity have been addressed within the scope of bicycle planning and policy. By adopting a heuristic approach, this paper delves into the current distributive justice debate and equity-based assessments, exploring representative literature concentrated on both social and spatial impacts of cycling. Findings from the United States, South America, Canada, United Kingdom and Europe reveal that often bicycle benefits such as infrastructure coverage, mobility and accessibility are unevenly distributed in cities, disregarding disadvantaged areas and vulnerable population groups. Whereas empirical evidence suggests that equity issues have been neglected during bicycle planning and decision-making processes, this review highlights methodological strengths and limitations, as well as future research pathways to support planners, politicians, and practitioners towards more equitable approaches.

Keywords: Bicycle planning; Equity; Accessibility; Sustainable mobility

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**1 Introduction**  
Within the sustainable development scope, active modes of transportation have been advocated as key low-carbon and affordable options, which can democratize mobility, improve the overall quality of life in cities, facilitate social cohesion, and ultimately increase access to opportunities for disadvantaged population groups (Karner, 2016). The promotion of the bicycle emerged as a crucial strategy to change the current car-oriented planning, which commonly focuses on the provision
of road infrastructure investments and supplies intended to facilitate the movement of motorized modes of transport in cities (Banister, 2008). Focusing on the equity impacts of bicycle planning and policy, recent studies acknowledged that the distribution of bicycle-related benefits, such as the cycling network coverage, mobility and accessibility gains, are often unevenly distributed amongst vulnerable population groups and disadvantaged areas in cities (Braun, Rodriguez, & Gordon-Larsen, 2019; Chandra, Jimenez, & Radhakrishnan, 2017; Clark & Curl, 2016; Houde, Apparicio, & Séguin, 2018; Kent & Karner, 2019; Pritchard, Tomasiello, Giannotti, & Geurs, 2019; Qian & Niemeier, 2019; Teunissen, Sarmiento, Zuidgeest, & Brussel, 2015; Tucker & Manaugh, 2018; Jueyu Wang & Lindsey, 2017). Such phenomenon might be more evident in the case of low-cycling cities (Aldred, Woodcock, & Goodman, 2016) or starter cycling cities (Silva et al., 2019) which are struggling to define and implement bicycle projects to reverse their car-oriented background, regardless of their residual bicycle mode share and cycling infrastructure. Indeed, within the decision-making process, the political resistance and lack of cycling commitment represent big challenges to overcome in these cities (Bicalho, Silva, Cunha, Teixeira, & Proença, 2019). Nevertheless, evidence suggests that the preferences and perceptions of disadvantaged or minority groups should be included as a crucial element of universal cycling design to normalize bicycle use in cities.

Therefore, this paper proposes a heuristic and critical review concerned with the question of how the bicycle, as a transport mode, and particularly the bicycle planning and policy can contribute to the development of more equitable cities and societies. This paper is organized into five sections. After this introduction, the second section provides the theoretical background encompassing equity assessments within transportation systems. By focusing on the social-spatial impacts of bicycle planning and policy, the third section describes the methodology applied to select and review the core literature. The fourth section highlights the dimensions of analysis, population segments as well as the often-applied methods conceived to measure the distribution of the bicycle-related benefits. Thereafter, the collected empirical evidence explores distinct distributive impacts across population groups and areas in both the global north and south. The last section critically summarizes the main findings and discusses the identified research gaps, pointing out some implications of the review for future research, policy, and practice.

2 Theoretical Background

The social and spatial impacts of transportation systems have been further scrutinized over the years, with scholars outlining their theoretical basis from the political philosophy literature and diverse theories of justice (Jones & Lucas, 2012; Martens, 2006; Pereira, Schwanen, & Banister, 2017). Conceptually, questions of social justice refer to a range of moral and ethical principles determined by the scope of the community’s values, regarding the treatment of all people (Deutsch, 1975). Within the transportation domain, scholars often investigate the distribution...
of transport ‘benefits’ and ‘costs’ in society (i.e., Distributive Justice), the procedures and process that determine rules and planning practices (i.e., Procedural Justice), and how to recognize and enhance civil participation into the decision-making process (i.e., Participatory Justice)(Pereira et al., 2017).

The dimension of distributive justice comprises theories that specify the extent to which distributions of resources, rights, costs, and burdens are acknowledged to be ‘just’ or ‘fair’ (Cook & Hegtvedt, 1983). Central to this debate, the transportation literature often proposes models of distributive justice and assessments based on distinct rules or principles, such as ‘equality’, ‘equity’, and ‘efficiency’(Cook & Hegtvedt, 1983; di Ciommo & Shiftan, 2017; Duran-Rodas, Villeneuve, Pereira, & Wulfhorst, 2020; Lee, Sener, & Jones, 2017).

The ‘equality’ approach was conceived with basis on the egalitarian theory (Lee et al., 2017), expecting that the transportation planning and policies should avoid favouring one individual or group over another, and therefore, the transportation benefits and costs should be equally distributed regardless the individual’s abilities and needs.

The ‘equity’ approach is concerned with the distribution of impacts among population groups which are segmented according to their abilities, needs and social-economic opportunities. In this case, the analysis focuses on how transportation planning could mitigate overall inequalities and improve social inclusion (Lee et al., 2017).

The ‘efficiency’ approach expects that resources are distributed according to people’s contributions, measured by utility and usage level, as well as their willingness and ability to pay. In this case, the demand guides the distribution of transportation costs and benefits (Duran-Rodas et al., 2020).

Amongst numerous principles or rules which may underly a given system of justice, the value of equity is commonly assessed within the distributive approach (Deutsch, 1975). Noteworthy, most of the transport-related literature treats ‘equity’ and ‘justice’ interchangeably, not drawing a clear distinction between these concepts (Pereira et al., 2017), even though previous studies already tried to solve the ambiguity encompassing the meaning of social justice, distributional effect, and equity in transportation (Geurs, Boon, & van Wee, 2009).

2.1 The Equity impacts of Transportation Systems

Overall, exploring the equity impacts of transportation systems often considers both spatial and social dimensions of analysis. While the former approach explores where inequities are occurring, the second focuses on vulnerable or disadvantaged populations, who are often marginalized by planning and decision-making processes.

According to the literature, a range of transportation impacts, ‘benefits’ or ‘costs’, can be considered in a distributive assessment (Geurs et al., 2009). For instance, the assessment of ‘costs’ often comprises the negative externalities and burdens of the transportation system (e.g., pollution, noise, accidents, congestion), the affordability of all types of services, and travel cost, whilst the distribution of ‘benefits’ often refers to the physical distribution of infrastructure, accessibility, availability, mobility, diversity, level of service and security (Beyazit, 2011).
To evaluate the distributive impacts of transportation, the segmentation of population is considered a crucial step, since it defines the degree to which several transport-related factors can be applied to an individual, differing greatly according to the context under analysis. Therefore, the deterrence factors that influence the transportation experiences of individuals can be categorized in terms of demographics (e.g., age, lifecycle stage, gender, household type, race, ethnic group), socioeconomic constraints (e.g., poverty line, income, travel budget, car ownership, education level), needs and abilities (e.g., physical and cognitive barriers, drive license, caregiver, language barrier), transportation mode (e.g., pedestrian, cyclists, public transit users) and trip type (e.g., commute, recreational, commercial or freight) (Litman, 2005).

Yet, there is no standardized set of methods, principles, and indicators for assessing equity in transportation, since this knowledge base is currently influenced by diverse disciplines, including spatial planning, human geography, social policy and sociology, public health, engineering, and transportation. Within the transportation sector, there is the challenge of translating theoretical concepts from social and economic sciences to measurable indicators and empirical evidence (Geurs et al., 2009). To capture a full picture of the equity impacts of transportation, a mixed-method approach is desirable.

3 Methodology
The promotion of the bicycle as a key transport mode spurs an increasing interest regarding how the cycling investments such as infrastructure, programs and services are distributed over cities and population groups, or in the other words, where and for whom cities are drifting such bicycle benefits. Aiming to explore how the current literature investigates the distributive impacts of bicycle planning and policy, the present paper conducted a comprehensive search of peer-reviewed papers published between 2010 and 2020, with the following keywords: ‘bicycle’, ‘equity’, ‘accessibility’, ‘social-spatial analysis’ and ‘distributive justice’. The academic databases and generic search engines used to gather such consistent literature were Web of Science, Google Scholar and Scopus. Accordingly, after filtering papers, books, and publications according to the intended analysis, the selected literature comprised 53 publications. The attributes for the characterization of the literature included the year, geographical area, the equity dimensions of analysis, the bicycle-related benefits, the population attributes as well as the methods applied.

All in all, the purpose of this review is threefold: firstly, it systematizes previous research encompassing the bicycle equity debate, exploring distinct methodological approaches and distributive measurements. Secondly, it examines the empirical evidence collected in both the global north and south, highlighting to what extent issues of equity have been considered within bicycle planning and policy over diverse political and social contexts. Lastly, the main research findings and limitations are critically discussed, offering theoretical and practical guidance towards future research pathways.
4 Bicycle Equity

The last decade observed a growing body of evidence encompassing bicycle-related equity assessments. Accordingly, research has shown that often disadvantaged and minority groups, such as low-incomers and communities of colour, are overrepresented in cycling (Rebentisch, Wasfi, Piatkowski, & Manaugh, 2019), and that cycling network provision, which is identified as a powerful strategy for mitigating the effects of motorization and increasing citizen’s mobility and accessibility (Tucker & Manaugh, 2018), often prioritize wealthy areas in cities such as gentrified neighbourhoods and privileged groups of societies (Lugo, 2013). Foremost, a range of scholars acknowledge that despite the demonstrated individual and societal benefits of the bicycle, the equity impacts are often overlooked during planning and decision-making processes, which ultimately produces an inequitable distribution of bicycle-related benefits (Lee et al., 2017), which intensify social and spatial inequities in terms of infrastructure provision, investments, and programs (Hosford & Winters, 2018).

4.1 Distributive framework

Commonly, the social and spatial impacts of the bicycle are explored within a two-step approach. On the one hand, when the spatial dimensions of analysis are highlighted, previous frameworks explored the neighbourhood as the unit of analysis, which is often characterized by demographic and trip factors (Conrow, Murray, & Fischer, 2018; Goodman & Aldred, 2018; Grisé & El-Geneidy, 2018; Lovelace et al., 2020). On the other hand, the social analysis focuses on population segments deemed to be in a situation of disadvantage and vulnerability, and therefore the analysis is commonly centred on census block groups. The identified frameworks generally assess the distribution of bicycle benefits, in terms of infrastructure coverage (e.g., cycling network, bicycle-sharing systems) (Bhuyan, Chavis, Nickkar, & Barnes, 2019; Flanagan, Lachapelle, & El-Geneidy, 2016; Wahlgren & Schantz, 2014), bicycle accessibility to opportunities (Barajas, 2019; Qian & Jaller, 2020; Reilly, Wang, & Crossa, 2020) and mobility (Barajas, 2019; Qian & Jaller, 2020; Reilly et al., 2020). Less frequently, the chosen benefits were the utility (Goodman & Aldred, 2018; Grisé & El-Geneidy, 2018), cycling uptake (Lovelace et al., 2020; Lubitow, Tompkins, & Feldman, 2019), service level (Qian & Jaller, 2020), security (Ravensbergen, Buliung, & Laliberté, 2020; Rebentisch et al., 2019), health improvements (Babagoli, Kaufman, Noyes, & Sheffield, 2019; Frater & Kingham, 2018) and inclusiveness (Böcker & Anderson, 2020). Outstanding, accessibility measures appear as valuable indicators to explore issues of equity, since they includes the utility of the destination in the distributive model. Indeed, accessibility refers to the precondition to a person fully participate in society and opportunities, which might require travelling to the place where those opportunities are located (Handy, 1996). The level of accessibility is dependent on resources like time, costs, cognitive skills which can increase or limit the ability to overcome distance and space. Thus, any person experiencing some resource limitation may experience a lower level of accessibility.
For measuring bicycle accessibility, most of the proposed methods were place-based, focusing on physical attributes of the land-use and transport system. The units of analysis were activities and opportunities perceived as essential for ensuring social inclusion and participation in society, such as employment, education, and services (Chandra et al., 2017; Chen & Wang, 2020; Qian & Niemeier, 2019; Rosas-Satizábal, Guzman, & Oviedo, 2020; Zuo, Wei, Chen, & Zhang, 2020). When assessing the distribution of cycling uptake, bicycle-related health gains, security and safety, research concentrates on the social dimension of analysis, highlighting discrepancies in terms of demographic, socioeconomic and ability factors. Accordingly, a range of studies revealed that cycling commuting continues remarkably gender unequal (Aldred et al., 2016) and that cycling practices are deemed to be more acceptable for middle-class, creative, and working-class people (Planagan et al., 2016).

Overall, census and surveys are the main databases for collecting individual factors, offering the baseline for the population segmentation process. According to the present review, the proposed frameworks focused on population profiles regarded as ‘minorities’, in a situation of social 'disadvantage' or 'vulnerability'. However, the literature does not draw a clear distinction between the meaning of these terminologies, which are often explored interchangeably. Therefore, the population is usually segmented according to socioeconomic factors (i.e., income, car ownership, poverty level, housing tenure and employment status), demographic characteristics (i.e., age, gender, ethnicity, race, citizenship status), abilities (i.e., education level, physical disabilities) and travel mode (i.e., cyclists and transit users). Overall, socioeconomic factors, such as income and car ownership appear as stronger cycling determinants within the bicycle equity analysis (Cervero, Sarmiento, Jacoby, Gomez, & Neiman, 2009; Lusk, Anastasio, Shaffer, Wu, & Li, 2017; Wahlgren & Schantz, 2014).

Within the segmentation processes, descriptive statistics are commonly applied to explore individual characteristics grouped in quartiles (Hamidi, Camporeale, & Caggiani, 2019; Kent & Karner, 2019), and quintiles (Tucker & Manaugh, 2018). Another technique refers to the development of composite indicators supported by statistical analysis (Braun et al., 2019; Chandra et al., 2017; Houde et al., 2018), such as the Principal Component Analysis, which is used to identify similar groups along with distinct characteristics or factors. To ensure that such an index correctly identifies similar groups, often a Pearson correlation matrix is conducted, followed by a standardization process (e.g., Z-score) of the selected indicators (J. Wang & Lindsey, 2019; Xiao, Wang, & Wang, 2018).

Noteworthy, there is an increasing application of both quantitative and qualitative methods to assess the distribution of bicycle-related benefits. In the former, previous frameworks deployed statistical analysis such as linear and multiple regression analysis (Houde et al., 2018; Maas, Attard, & Caruana, 2020; Qian & Jaller, 2020), Principal Component Analysis (Hosford & Winters, 2018), Cluster analysis (Pritchard et al., 2019; Rosas-Satizábal et al., 2020), GIS-based network analysis (Hosford & Winters, 2018; Kent & Karner, 2019; Tucker & Manaugh, 2018) and descriptive analysis of census and survey data (Barajas, 2020; Lubitow et al., 2019; Ravensbergen et al., 2020). In the latter, assessments included ethnographic studies.
(Lugo, 2013; Parker, 2019), in-depth and semi-structured interviews (Candipan, 2019; Lusk et al., 2017), observation (Candipan, 2019; Lusk et al., 2017), and focus groups (Frater & Kingham, 2018). Recently, scholars drifted attention towards methods and indicators from economics, which were originally conceived to measure discrepancies in terms of income such as the Gini index and Lorenz curve (Chen & Wang, 2020; Duran-Rodas et al., 2020; Pritchard et al., 2019), the Theil Index (Hamidi et al., 2019; Zuo et al., 2020), the Atkinson index (Rosas-Satizábal et al., 2020) and the Palma Ratio (Rosas-Satizábal et al., 2020). All in all, these authors adapted such indicators by replacing income with the cumulative levels of bicycle accessibility.

Based on the Gini coefficient and the graphical Lorenz Curve, Pritchard et al. (2019) explored the potential of cycling in reducing spatiotemporal inequalities over trapezoidal urban areas, indicating zonal values of job-accessibility to the population (Hamidi et al., 2019). Likewise, Wang and Lindsey (2017) applied this method to evaluate how bicycle accessibility was distributed amongst subgroups with potentially greater transportation needs. Such a vertical equity assessment relied on a composite indicator that aggregates six indicators of a potentially disadvantaged subpopulation (i.e., car ownership, poverty level, ethnicity, race, younger and elderly) developed at the block group level. A recent study readjusted the formulation of the Theil Index by replacing income with a composite bicycle accessibility indicator, assessing the contribution of individual characteristics (e.g., citizenship status) to the total spatial inequality (Hamidi et al., 2019). Originally, the Theil index is a decomposable technique used to measure income inequality, revealing an entropic distance or how far away is a population from the egalitarian state. Likewise, the Atkinson index also has an entropic structure and is sensitive to differences in the distribution scale and especially at the bottom, therefore being useful to determine which part of the distribution contributes most to the observed inequality (Zuo et al., 2020).

The distributive assessment that makes use of the Palma ratio (Rosas-Satizábal et al., 2020) explored disparities between the bottom of the distribution, represented by the bottom 40% of the sample and those at the top 10%, highlighting differences between the poorest and the richest, in terms of bicycle accessibility to employment and education opportunities.

### 4.2 Empirical evidence

The present review outlines strong evidence that the decision-making and bicycle planning process often target wealthy areas and privileged population groups in cities. This phenomenon is mostly observed in countries with higher social disparities in terms of income, education attainment, employment access and reliance on public transportation, such as the United States, Colombia, and Brazil (Pritchard et al., 2019; Teunissen et al., 2015; Tucker & Manaugh, 2018). The empirical evidence observed in the United Kingdom encompasses issues of gender and age, and explores the potential of the bicycle as a transport mode in promoting social inclusion and participation for vulnerable (i.e., women) and minority profiles (i.e., younger, elderly) (Clark & Curl, 2016; Goodman & Aldred, 2018). In Canada,
such a distributive framework mostly investigates the distribution impacts across low-incomers and immigrants (Hosford & Winters, 2018; Houde et al., 2018). In the United States, an analysis of Bicycle Master Plans implemented in 22 large American cities suggested that the development of the cycling network disregards areas with lower socioeconomic status, lower educational level, and higher proportions of non-white residents (Braun et al., 2019). In El Paso, the distribution of bicycle lanes and the accessibility improvement is concentrated in the downtown area being poorly connected to public transportation hubs, jobs opportunities and the low-income workers group (Chandra et al., 2017). In Chicago and Philadelphia, groups in disadvantaged communities have a low level of bicycle accessibility, when compared to areas with a more affluent and white population (Qian & Jaller, 2020). In Tampa, the accessibility provided by the local bicycle share scheme is unevenly distributed between different sociodemographic groups, being more accessible for whites, males, individuals from higher-income households and people ageing between 18 and 35 years old (Chen & Wang, 2020).

Results from the South American context also highlight the uneven distribution of bicycle benefits. For instance, in Bogotá, Colombia, the accessibility provided by the cycling network does not attend most of the low socioeconomic households (Teunissen et al., 2015). The same phenomenon was identified in Brazil, where the bicycle network in Rio de Janeiro and Curitiba have proved to benefit the wealthiest neighbourhoods, favouring the higher income population quintiles (Tucker & Manaugh, 2018). In São Paulo, there is an uneven distribution of bicycle accessibility to employment measured by Gini coefficients, with most of the improvements centred in the middle to high-income areas. Peripheral areas, with higher dependency on public transportation modes and higher poverty level, had the lowest improvement (Pritchard et al., 2019).

In Canada, previous research conducted in Montreal revealed that the cycling network provision improved the accessibility level for low-incomers, recent immigrants, and seniors. However, bicycle accessibility for children decreased, especially due to the perception of insecurity when cycling (Houde et al., 2018). Another research, which assessed the distribution of bicycle share level of service in Vancouver, Toronto, Ottawa and Montreal revealed that advantaged areas, depicting a lower level of deprivation in terms of education, income and unemployment, have greater access to bicycle share service (Hosford & Winters, 2018).

In the United Kingdom, substantial inequalities were found within cycling commuting in terms of gender, age, disability, and ethnicity (Goodman & Aldred, 2018). In Glasgow, a low percentage of the population, around 15%, has the potential to fully benefit from the accessibility provided by the local bicycle-sharing system (Clark & Curl, 2016). All in all, although cycling to work has increased in a relatively equitable manner between 2001 and 2011, the discrepancy between English towns indicates a crucial challenge regarding future bicycle policies and investments (Goodman, Panter, Sharp, & Ogilvie, 2013).

In Europe, the limited empirical evidence suggests more significant differences across the spatial dimension of analysis than the social one. However, it is crucial to remark that such assessments lack crucial demographic and socioeconomic parameters related to income and poverty level, whereas these data are not
generally available in current open-source European databases at the smallest census tract level. Thus, previous research conducted in Malmö, Sweden, revealed the bicycle-sharing station is generally equitably distributed, with more significant differences between peoples with similar background living in different areas rather than people with different backgrounds living in the same area (Hamidi et al., 2019).

In Munich, Germany, the same phenomenon was observed, with the local bicycle-sharing system serving both privileged and underprivileged groups (Duran-Rodas et al., 2020). In the capital of the Gran Canarias, spatial factors related to aesthetics, greenery, bicycle paths, and density of activities positively influenced the level of cycling use (Maas et al., 2020). In the Netherlands, the increasing aggregate cycling volumes in cities were mainly sensitive to changes in the composition of the population, especially for the elderly and immigrants (Harms, Bertolini, & te Brömmelstroet, 2014).

5 Discussion
Over the last decade, researchers developed distributive frameworks for assessing the equity impacts of the bicycle-related benefits over areas and population groups. Amongst diverse methodological approaches for conducting such assessments, the use of accessibility measures and socio-economic composite indicators, have been proven to be useful for discussing bicycle equity. Indeed, academia and transport agencies commonly use accessibility planning theory to examine the social impacts of transportation investments (Geurs & van Wee, 2011).

Nevertheless, despite the increasing attention towards socioeconomic factors such as income, car ownership and employment status, most of the present research overlooked factors related to individual needs and abilities (e.g., physical, and cognitive constraints). Regarding the accessibility assessments, the analysis often makes use of arbitrary impedance functions (Iacono, Krizek, & El-Geneidy, 2010; Vale, Saraiva, & Pereira, 2016), limited at the smallest census data units, represented by census block groups, therefore disregarding the granular scale represented by the cyclist. Indeed, the full integration of the individual component in accessibility measures remains challenging, especially in the case of the bicycle due to the general lack of high-resolution data at the individual level. Future research could explore perceptions of bicycle accessibility, amongst vulnerable or disadvantaged groups, to provide a more generalizable and practically useful output.

Accordingly, measuring the distribution of bicycle-related benefits is challenging due to a lack of clear and suitable indicators for measuring equity progress. To fill this gap, recent research adapted statistical analysis and distributive measures from economics such as the Gini coefficient & Lorenz Curve, Theil Index and Palma ratio. Nonetheless, it remains unclear how such frameworks, which deals with increasing complexities, could be useful and practical to support the decision-making processes. Thus, reinforcing the knowledge exchange between academia and professionals is a crucial step that needs careful attention.
Most of the current literature developed ex-post analysis, focusing on the equity impacts of cycling after the implementation of the bicycle-related project or investment. Although the ex-post analysis of equity gives some directions on how to manage investments and revenues (Ramjerdi, 2006), the current approaches do not give directions on how projects should be conceived to enhance social inclusion and spatial cohesion. This lack of knowledge may perpetuate or exacerbate inequitable practices within the bicycle planning and decision-making process. A crucial research pathway in this agenda refers to the development methods for evaluating bicycle plans and projects from an ex-ante perspective, which could create and enhance political awareness of the social benefits of cycling investments, during the initial phases of planning and decision-making processes. Supported by the present literature review, this paper demonstrates that the debate encompassing bicycle equity is still in the earlier stages. To better reflect the spatial-social context under analysis, the full integration of equity assessments within bicycle planning is desirable. Likewise, the development of tools for comparative analysis tailored for different planning scenarios, could support future projects and interventions towards more equitable solutions, ensuring social inclusion and spatial cohesion in cities.

References


