Future Cities and Environment
ISSN 2363-9075 Volume 11 (2025)
© Cerebration Science Publishing
https://doi.org/10.70917/fce-2025-033
Article

Diverse Opportunity Potential through Geographic Accessibility Modeling as a Basis for Planning towards the 15-Minute City and Spatial Justice

Juan Esteban Aristizábal Salazar*, Santiago Wagenaars Rincón and Diego Alexander Escobar García

Grupo de Investigación en Movilidad Sostenible – GIMS. Universidad Nacional de Colombia Sede Manizales, Manizales 170004, Colombia; swagenaars@unal.edu.co; daescobarga@unal.edu.co
* Corresponding author: jaristizabals@unal.edu.co

Abstract: Many cities are currently rethinking their urban planning with the aim of prioritizing proximity between places of residence and essential services. This approach, promoted mainly in European countries under the concept of the "15-minute city," seeks to minimize travel times through the use of active modes of transport, such as walking and cycling. To achieve this, a balanced redistribution of urban services is proposed, harmonizing land use with improvements in active transportation infrastructure. However, in Latin America, urban development continues to favor fragmentation, with growth that relies on long commutes and encourages reliance on private vehicles, undermining public transport systems and limiting access to sustainable modes. This study evaluates pedestrian accessibility in the city of Manizales (Colombia), applying a cumulative opportunities potential (COP) model for six types of facilities. The results show a concentration of services in central areas and a marked spatial inequality affecting urban peripheries. To reduce the socio-spatial gap and improve the quality of life, it is suggested to promote proximity policies that improve the distribution of opportunities and strengthen walking access for all inhabitants.

Keywords: spatial equity; urban services; proximity; urban mobility; geographic accessibility

1. Introduction

The phenomenon of urban inequality has been extensively studied and debated globally (Moreno, 2020), yet its reduction policies remain marginalized in public and administrative decision-making. In Latin America, the most unequal region in the world (Frenzel and Casares, 2023), with approximately 80% of its population living in urban environments, it is imperative to advance in public policies that allow for the reduction of inequality in cities from various fronts of action, including housing policies (Desmond, Gershenson and Kiviat, 2015; Gilbert, 2004; Laguecir and Hudson, 2024). These include mobility (Dureau et al., 2013; Tiznado-Aitken et al., 2023; Zhang et al., 2024), services and opportunities (Moreno et al., 2021; Mouratidis, 2024), public space (Swapan, Aktar and Maher, 2024; Wright Wendel, Zarger and Mihelcic, 2012), and others.

In urban areas, the concentration of urban development has been observed to occur in the most favored locations (Aristizábal, Sarache and Escobar, 2023), which has contributed to the widening of the socio-economic gap between different social sectors. It is imperative that urban development is aligned with land use policies, transportation policies and environmental quality (Waddell, 2002). The concentration of urban development has resulted in the less favored population being compelled to undertake longer commutes to access daily activities (Weiss et al., 2018), including work, study, health, recreation, culture, and other essential urban services.

In this sense, in recent years there has been a notable increase in the use of urban approaches in the search for the decentralization of territorial development and the generation of a decentralized urban

Copyright: © 2025 by the authors

model that favors the reduction of segregation in cities. The concept of the 15-minute city represents a further development of these approaches, seeking to rethink cities based on the decentralization and redistribution of basic urban activities and services. The objective is to ensure that all inhabitants of a territory can have access to most of these services in the proximity of their homes. In practice, this concept seeks to decentralize urban activity typically concentrated in economic poles, favoring a transition from dormitory neighborhoods. (Marín-Cots & Palomares-Pastor, 2020) towards neighborhoods with a greater diversity of services (Zumelzu-Scheel, 2016), thus reducing the necessity and duration of urban journeys and increasing the probability of utilizing active transportation modes (walking and cycling) from residential locations to the urban activities required for sustenance and the exercise of citizen rights.

This research focuses on a medium-sized city such as Manizales (Colombia), but its relevance transcends this context. In future research, it would be valuable to conduct a comparative analysis with other cities that present similarities in the proximity of basic services, such as Paris (France), Barcelona (Spain) or La Plata (Argentina). These cities, although with different urban, socioeconomic, and topographic contexts, share key characteristics in the distribution of essential services, the promotion of pedestrian accessibility and active mobility. In addition, a cross-country comparison would allow to analyze how urban policies, topography and socioeconomic dynamics influence the implementation of proximity models, such as the 15-minute city concept.

In terms of urban mobility, Latin American city governments have prioritized the development of transport infrastructure construction policies (Arellana et al., 2021) over policies oriented to accessibility and proximity of services (Elldér, Haugen and Vilhelmson, 2020). This has resulted in an increased reliance on private motorized modes of transport overactive and collective modes of transport (Sierra Muñoz et al., 2024; Urry, 2004).

The implementation of mobility policies that prioritize private motorized transportation has been identified as a contributing factor to adverse outcomes, including traffic congestion (Hsu and Zhang, 2014), road accidents (Klanjčić et al., 2022), and noise pollution (Bao et al., 2022). Furthermore, the prioritization of infrastructure policies over proximity policies has resulted in the centralization of cities, which has in turn led to a reduction in the provision of services at the neighborhood scale and the segregation of effective and fair access to opportunities within urban areas. Additionally, the prioritization of infrastructure policies has contributed to increased levels of air pollution (Wu et al., 2022).

The transition towards the redistribution of urban activity is intended to facilitate citizens' access to goods and services (Wu et al., 2021). It involves the decentralization of economic poles, the promotion of measured and efficient densification, and improvements to accessibility by reducing the need for commuting and the speeds associated with it. This (Levine et al., 2012) has the additional benefit of consolidating improvements in urban quality of life, promoting active transportation, greater community life, and other factors that are positively impacted through proximity and urban accessibility policies (Bannaga, 2018; Ferrer-Ortiz et al., 2022).

The decentralization of urban activity should be accompanied by the implementation of land use policies that prioritize mixed-use over mono-functional zone policies. Mixed land use has the potential to reduce greenhouse gas emissions by promoting transport modes with lower environmental impacts, including public transport (Li et al., 2022) and walking (Seong, Lee and Choi, 2021). Furthermore, mixed land use has been shown to positively influence the health of residents in diverse neighborhoods, and a greater mix of services is essential for the creation and promotion of more sustainable cities (Shekfa and Ahmed, 2022). This is evidenced by studies which have shown mixed land use to contribute to improved cognitive function (Finlay et al., 2023), reduced obesity (Jia et al., 2020), and other factors that contribute to an improved quality of life at the neighborhood level (Manaugh and Kreider, 2013). The provision of proximity services exerts a beneficial influence not only in urban environments but also in rural areas, where land use mix can contribute to the revitalization of local economies and the promotion of development (Chen et al., 2022).

Spatial injustice can be characterized in five categories: exploitation, marginalization, powerlessness, cultural imperialism, and violence (Young, 1990). A substantial body of research has investigated the influence of the neighborhood in which individuals are raised on their subsequent development, with particular emphasis on factors such as health in later life (Chan et al., 2022), satisfaction in personal relationships and social well-being (Mouratidis, 2018), and comprehensive child development (Villanueva et al., 2016).

In particular, Cumulative Opportunity Potential (COP) models are employed, which assess the number of nodes of interest situated within a specified temporal radius from a point of origin. This is a diagnostic tool for identifying marginalization and measuring spatial injustice (Fainstein, 2013) in the study city. The six services considered are: worship, culture, education, recreation, health, and public services.

Manizales is an Andean city located on the central mountain range at an altitude of 2150 m above sea level as shown in Figure 1 below. It is characterized by a topography comprising a series of broken high mountains. The city has an estimated population of 464,000 (2024 estimate), with a significant proportion of the population comprising university students and senior citizens. The city's mobility system comprises 83 urban public transportation routes, a free public bicycle system (SBP) with 10 stations, and an aerial cable system with two operational lines and a third currently under construction.

Figure 1. Manizales Location. Own elaboration.

The Origin Destination Matrix (Alcaldía de Manizales, 2017) indicates that 750,000 trips are made on a daily basis in Manizales. Despite its topography, the most prevalent mode of transportation is walking, accounting for a 29% share of total trips. This is followed by transit, which encompasses bus and cable-car, at 28%. Passenger cars and motorcycles account for 20% and 12% of trips, respectively.

In line with this research Escobar, Sarache and Jiménez-Riaño (2022), analyzes the impact of the aerial cable as a means of mass public transport in reducing emissions and improving accessibility in the same city of study, evaluating the implementation of this mass transport system consisting of urban cable cars in Manizales, generating benefits in multimodality and reducing carbon emissions.

Next, the stages that make up the methodology used in the research will be presented, followed by the results, a brief discussion of them, and finally, the main conclusions of the research.

2. Methodology

The research methodology comprises three main stages: (1) the collection and consolidation of baseline information; (2) the modeling of the Cumulative Opportunity Potential (COP); and (3) the creation of percentage targets of population coverage by socio-economic levels. The methodology is best and most perceptibly explained in the following flow chart nomenclature as Figure 2.

2.1. Stage 1: Collection and Consolidation of Baseline Information

The initial step involved the collation of databases from the Manizales Land Management Plan of 2017 (POT, acronym in Spanish), which encompasses the collection of primary data during its diagnostic stages. This data encompasses urban activity nodes within the city, categorized into six groups (Table 1). This categorization was adapted to align with the context of the territory and the available analysis inputs in Manizales. This was based on the essential social functions of the settlements, as outlined by Moreno et al. (2021).

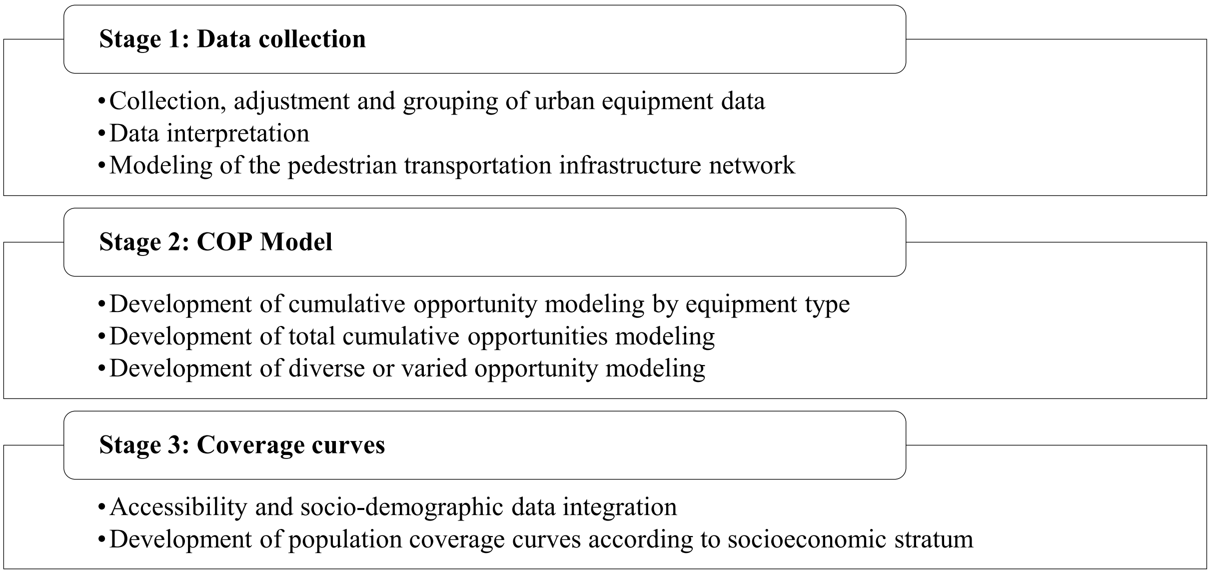

Figure 2. Methodology flow chart. Own elaboration.

Following the collection and consolidation of essential service facilities, the pedestrian transportation network of Manizales was optimized using geographic information systems (GIS). Using software tools, arc lengths were calculated, and average walking speeds were assigned, adjusted by a reduction factor based on slope, depending on whether the direction of travel was uphill or downhill. With this data, the walking time for each arch was determined, incorporating all the variables necessary for the accessibility calculation. This variable pedestrian speed, based on the slope of the links, is especially relevant in cities with steep topographies (Suárez-Celis et al., 2024), as these topographic constraints significantly influence the speed of travel for all modes of transportation.

Table 1. Categories and equipment considered in this research. Own elaboration

Amenity Category	Equipment	Number of amenities
Public services	Airport, transit stations, government buildings, police stations, courthouses, community service centers, rescue, and emergency corps.	46
Health and welfare	Hospitals, clinics, medical centers, health posts, Shelters, homes for the elderly, and pharmacies.	70
Education	Gardens, schools, colleges, and universities	174
Culture and entertainment	Libraries, cultural centers, theaters, conventions, and event centers.	16
Recreation and sports	Parks, squares, small squares, sports fields, coliseums, stadiums, and sports arenas	177
Worship	Churches, temples, parishes, chapels, convents, and cemeteries.	76

Figure 3 below shows the map of the pedestrian network and the main transportation network of the city of Manizales, where the facilities used for the calculations of the study are georeferenced, along with all available services, such as health, education, culture, recreation, worship, and public services. This map makes it possible to analyze the spatial relationship between facilities and transport infrastructure, showing how they are concentrated and distributed along the main mobility network. In addition, visualization allows observing the proximity of amenities to strategic transportation nodes, as well as their arrangement in densely urbanized areas or in more peripheral areas. The inclusion of this information is fundamental to understanding user mobility dynamics, as it reflects not only the connectivity characteristics of the network, but also how this influences effective access to the different services and daily activities that sustain urban life.

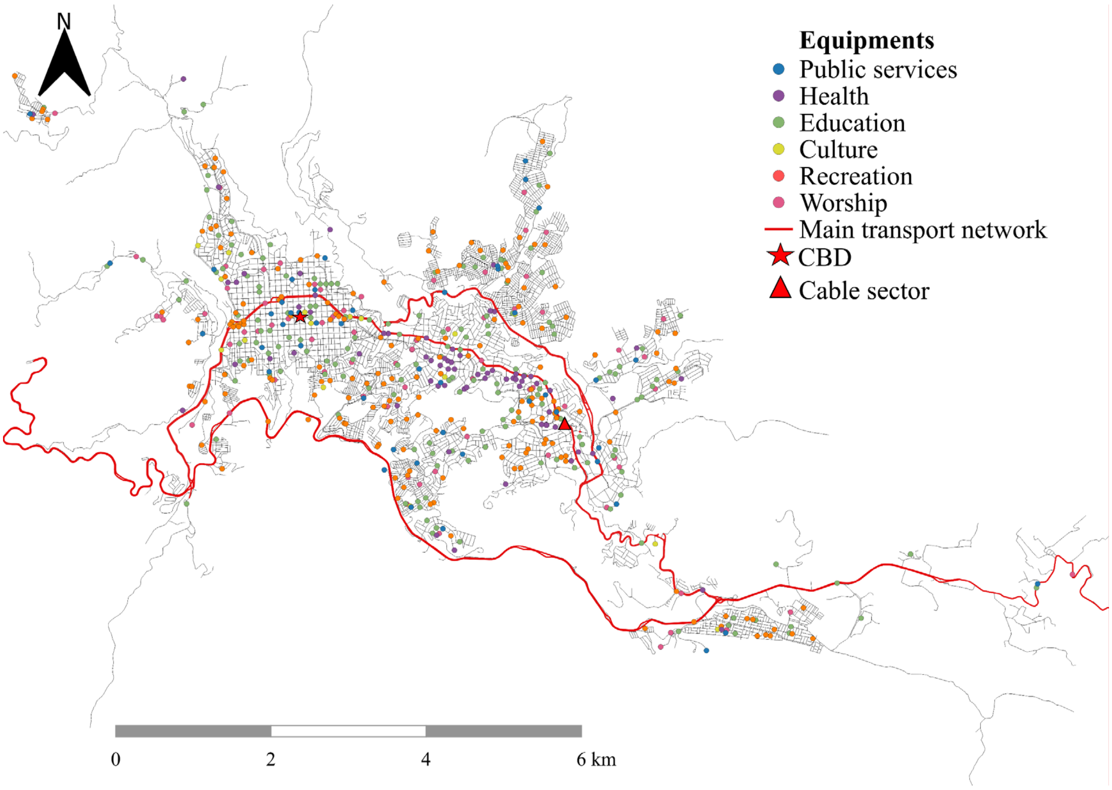

Figure 3. Equipment map. Own elaboration.

2.2. Stage 2: Modelling of Cumulative Opportunity Potential (COP)

Secondly, the objective of COP models is to characterize the coverage of services in the proximity of households in Manizales. The results of these models enable the amount of services available to people near their homes to be characterized spatially within the city.

To calculate the geographic accessibility model based on accumulated opportunities, a mathematical formulation was used (Equation 1) that incorporates the travel impedance (Cij) between all the nodes of the road infrastructure network. Each node was considered as origin (j) or destination (i), and the shortest path was determined using a statistical algorithm (Wu and Levinson, 2020). The pedestrian infrastructure network was modeled considering the length of the arcs and the travel times associated with each one, data extracted from the corresponding vector file (shape). This procedure was carried out under a pre-validation scheme to ensure the reliability of the results obtained.

$$A = \frac{\sum_{i=1}^{J}\sum_{j=1}^{J} c_{ij}}{J-1} \qquad (1)$$

Pedestrian accessibility was then calculated as the average travel time from each network node to the equipment nodes. The data were filtered to include only times less than or equal to 15 minutes, according to the methodological framework of temporal proximity. Isochronous curves were generated with the results using the ordinary Kriging geostatistical method, applying a linear semivariogram as a structural model. This method, based on spatial correlation and distances between observed values, allowed accurate prediction of travel times Escobar, Montoya and Moncada (2024). Previous studies validate the effectiveness of this approach in research related to transportation and mobility.

Accordingly, seven COP models are applied, delimiting a time scope of 15 minutes walking distance from the subject's place of residence. Each model individually assesses the accessibility to the six categories of facilities. Subsequently, two supplementary accessibility models are devised: (i) total cumulative opportunities (COP) is presented without differentiation of facility category, and (ii) diverse or varied opportunities (quantifying the range of services reached by type). Being the main difference between them the range of facilities that they reach in the count for the isochronous curves, the model of accumulated opportunities has as a limit the number of facilities for each of the categories and the diverse model has as a limit the number of facilities defined in the methodology.

This approach provides tools to characterize the coverage of proximity to services location in

Manizales, and to broaden the discussion about urban development models aimed at the proximity of activities offered to citizens. This is being done to reduce the need to travel and increase the availability of personal time. Additionally, active modes of transportation gain probability of use, and at the planning level, the provision of public transportation infrastructure is facilitated.

2.3. Stage 3: Coverage Curves by Socioeconomic Levels

In stage 3, the construction of the percentage curves segmented by socioeconomic level is conducted. This process is based on the data generated by geographic accessibility models. To achieve this, an intersectional analysis is performed, linking the layer resulting from the accessibility model with a layer of sociodemographic information, which mainly includes the socioeconomic stratum and population distribution. Once this information is consolidated in a database, it is possible to generate cumulative percentage graphs representing the coverage for each of the services studied.

The main objective of these curves is to identify the coverage of each of the seven services, characterizing the socioeconomic levels that have a higher percentage of access based on proximity to services. In addition, these curves allow us to analyze patterns of inequality in the distribution of services, identifying significant gaps between the different socioeconomic levels. This information is fundamental to guide urban planning strategies and public policies that promote a more equitable distribution of resources. At the same time, the curves provide a solid basis for supporting research conclusions by offering graphical and numerical tools that facilitate the interpretation of the data.

Limitations of the methodology

The methodology employed in this study offers valuable insights for the analysis of geo-referenced data and the determination of spatial equity in the different study areas. However, it also presents limitations that could be addressed or deepened in future research. First, it does not consider the availability, quality and capacity of the services evaluated, which limits its applicability for assessing individual requirements, since the focus is on collective access.

In addition, the Cumulative Opportunity Potential (COP) model assumes uniform behavior across socioeconomic strata, which does not reflect the diversity of mobility patterns that vary by socioeconomic level. For example, some strata may face additional complexities, such as safety concerns, infrastructure quality or limited access to transportation options, variables that the model does not take into account as they are considered latent.

Finally, the accessibility models used rely on public or open databases, mapping, and information, which may introduce biases or lack of representativeness. It is crucial not only to assess the quantity of data, but also its quality. These limitations represent opportunities for future research, where current methodologies could be improved or complemented in order to overcome these gaps and provide a more robust and complete analysis.

3. Results and Discussion

3.1. Accessibility Model Results for Equipment Categories

The results and discussion of the COP accessibility models used are presented below. Figure 4 shows the results of measuring accessibility to the various categories of facilities considered within a 15-minute walk from home. The maps serve as a spatial reference, illustrating the city's primary system of transportation infrastructure and the two principal urban economic poles of the study area: the historic center (Central Business District - CBD) and the Cable Sector. These areas collectively encompass a significant portion of Manizales' urban activity.

The mobility corridor in the central business district (CBD) and the Cable Sector, corresponding to Santander Avenue in Manizales, represents the most significant transportation infrastructure at the urban level in the city. It has facilitated the consolidation of a considerable number and diversity of urban services along its axis, as well as a combination of residential developments that are predominantly occupied by individuals from high socioeconomic strata.

The central area of Manizales demonstrates a high level of accessibility to worship services, particularly near the Central Business District (CBD) and extending toward the northern and northeastern parts of the city. This accessibility is most evident in a strip connecting the CBD to the Cable Sector, where the proximity to worship facilities remains consistent. However, as one moves toward the western and eastern edges, accessibility gradually decreases, indicating a reduced presence of these services in those areas. In contrast, the peripheral zones of Manizales exhibit lower levels of accessibility due to a sparser distribution of worship services, which limits ease of access for residents in these neighborhoods. This pattern underscores a centralization of services in the urban core, leaving the outskirts underserved and highlighting the need for a more equitable distribution of resources across the city.

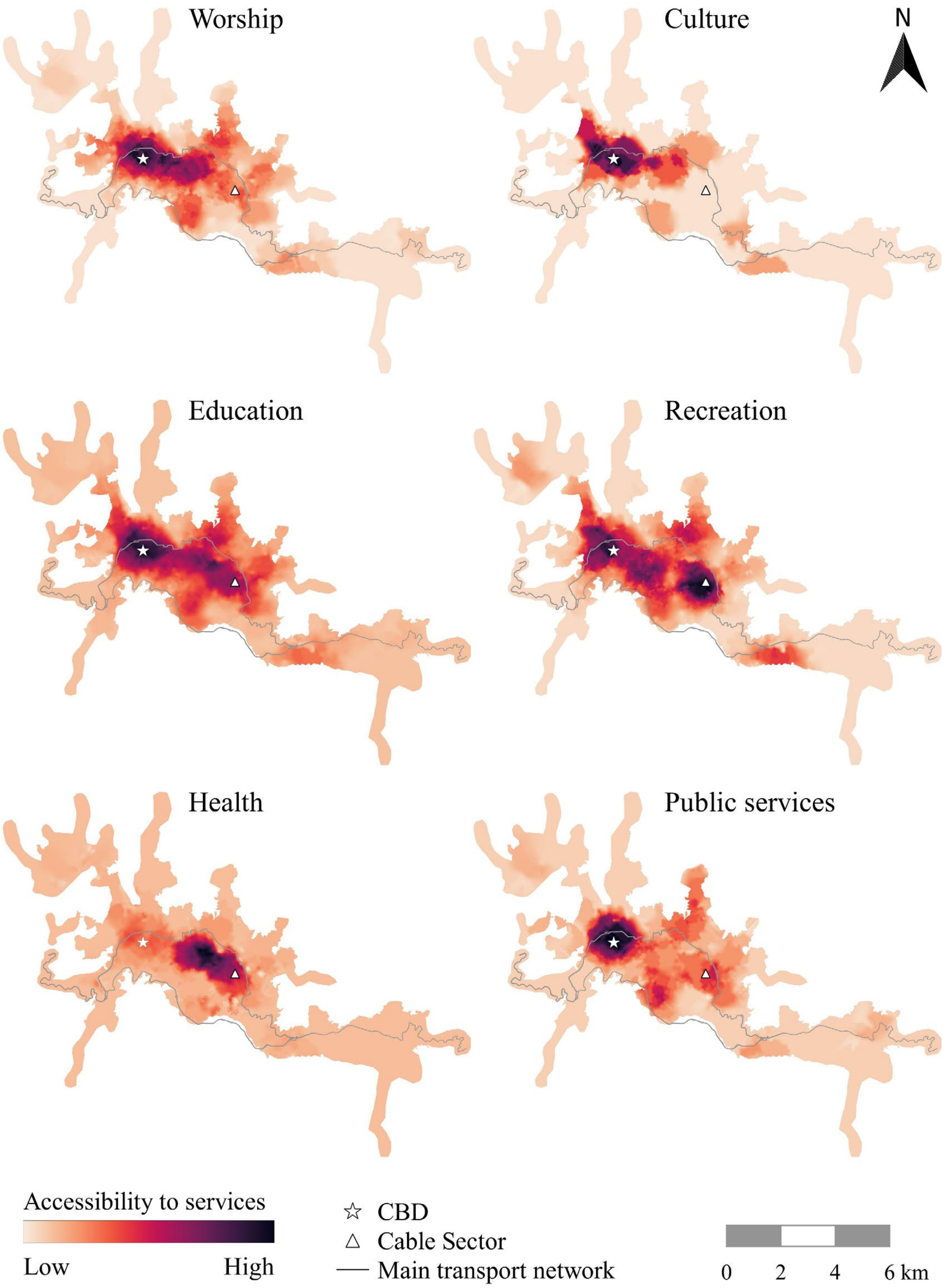

Figure 4. Accessibility to equipment categories. Own elaboration.

The accessibility of cultural services in Manizales is notably concentrated around the Central Business District (CBD), with a particularly high presence to the north and northeast of this central area. However, unlike worship services, cultural services display a slightly more homogeneous distribution, extending over a smaller but denser area toward the eastern parts of the city. This suggests a modest attempt at decentralization, yet the overall pattern still reveals a strong centralization of these services near the urban core and adjacent neighborhoods. Similar to the distribution of worship services, the peripheral zones experience significantly lower levels of accessibility to cultural amenities, reflecting an uneven spatial distribution that disadvantages these outlying areas. This disparity underscores the pressing need for targeted interventions to improve cultural service accessibility in the city's outskirts and promote a more equitable distribution of these vital urban resources, thereby addressing existing accessibility gaps.

The mobility corridor that connects the Central Business District (CBD) with the Cable Sector offers high accessibility to educational services, situated along an avenue with adequate physical characteristics, especially for motorized modes of transport. However, there is a gradual decrease in accessibility outside this mobility corridor, with a significant drop in the peripheral areas of the city, suggesting a centralized distribution of educational opportunities in the urban area. Furthermore, coverage is observed along a north-south axis and inversely.

The accessibility of recreational services exhibits a comparable pattern to that of educational services, albeit with a relatively higher concentration in areas proximate to the Central Business District (CBD) and the Cable Sector. When compared to educational services, a higher intensity in the accessibility index is observed along the North-South axis. Towards the eastern and western periphery of the city, accessibility decreases progressively. The southernmost areas also demonstrate low accessibility to these services, indicating that recreational opportunities are more concentrated in the more important urban economic centers of the city.

The accessibility of health services is predominantly high, with a concentration around an intermediate zone between the Central Business District (CBD) and the Cable Sector, extending significantly towards the Cable Sector. As with other services, accessibility to health services is considerably low towards the periphery of the city, particularly in residential areas.

The area connecting the Central Business District (CBD) with the Cable Sector exhibits high accessibility to public services, with a relatively wide distribution to the north and northeast. However, accessibility is significantly lower to the south and east, indicating a concentration of these services in the central urban area. Of the six types of services analyzed, this particular type demonstrates a greater concentration in a specific area of the city (CBD).

In summary, the results highlight a clear centralization of services in Manizales, particularly around the CBD and Cable Sector, with high accessibility to worship, cultural, educational, recreational, health, and public services. However, accessibility decreases significantly in peripheral areas, where services are sparsely distributed, leaving residents in these neighborhoods underserved. This spatial inequality underscores the need for targeted urban policies to promote a more equitable distribution of resources across the city.

3.2. Accessibility Model Results for Total and Miscellaneous COPs

Figure 5 presents the total and diverse cumulative opportunity potential (COP) accessibility models. The total opportunity COP model characterizes the level of accessibility to services within a 15-minute walk from homes, irrespective of the type of service. It is evident that the corridor between the CBD and the Cable Sector exhibits high levels of accessibility in comparison to other areas of the city. Furthermore, in accordance with the trend observed in the COP models for each type of service, the peripheries of the city demonstrate low levels of accessibility to the services under consideration.

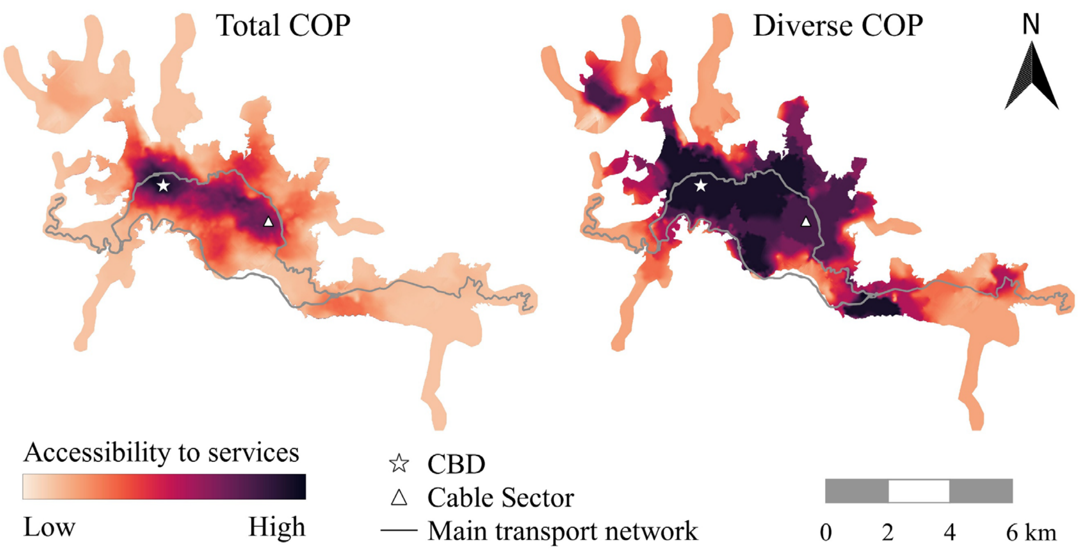

Figure 5. Accessibility of total and miscellaneous COPs. Own elaboration.

The opportunity diversity COP model characterizes the number of types of services that can be accessed within a 15-minute walk from homes, jobs, and exit points. It is clear that, unlike the service type models and the total opportunity COP model, there is not a high concentration of diversity in the accessibility of the diverse types of services considered. A large polygon of high accessibility to diverse opportunities can be seen extending from the historic center of the city (CBD), towards its related neighborhoods; in addition, an extension of this polygon of high diversity of opportunities towards the north of the city can be observed, a trend that is not present in any of the other COP models developed.

Furthermore, two isolated polygons situated on the southern periphery of the city exhibit high accessibility to a multitude of opportunities. Despite the absence of comprehensive accessibility to total opportunities, these polygons represent neighborhood-scale areas where inhabitants can conveniently access a range of essential services within a 15-minute walking distance.

The historic center of the city (CBD) and part of the mobility corridor that connects it with the Cable Sector are the only areas of the city with high accessibility to both total services and their diversity. The CBD is the consolidated economic pole of greatest urban relevance in Manizales, concentrating an important part of the urban development, economic and social activity of the city. It is characterized by the presence of small to large economies and urban opportunities.

3.3. Coverage Curves

Through the mathematical formulation of the geographic results, Figure 6 illustrates the population coverage curves for each of the six services, with the data presented in a manner that allows for the discretization of the socioeconomic stratum of households. This stratification enables a more detailed analysis of how access to services varies across different segments of the population. In Colombia, the socioeconomic stratum is an indicator associated with housing, reflecting factors such as infrastructure quality, neighborhood characteristics, and the provision of utilities, which collectively provide valuable insight into the living conditions experienced by its inhabitants. Consequently, it serves as a dependable proxy for estimating household income levels and highlights disparities in service accessibility, which are often tied to broader patterns of social and economic inequality. By incorporating this variable, the analysis gains a nuanced understanding of how geographic and socioeconomic factors intersect to shape access to essential services.

It is notable that, within the study area, households with middle socioeconomic status (i.e., those with middle incomes) demonstrate superior access to worship, cultural activities, and public services compared to the other two socioeconomic strata. Conversely, households with high socioeconomic status (i.e., those with high incomes) exhibit greater access to recreation and health services. Additionally, the low socioeconomic stratum exhibits the highest prevalence of access to services that are more deficient than those available to the other strata.

4. Conclusions

Inequality is present globally from various perspectives. The predominant development in Latin America has favored urban fragmentation with the growth of cities around the need for long commutes, limiting the potential for the use of active modes of transport and hindering the planning of public transport systems.

Modern urban development must consider the articulation between land use policies, transportation policies and environmental preservation. In terms of land use, cities should advance policies that allow for a decentralization of urban activity, in order to de-escalate urban life towards activities with a neighborhood and local focus, favoring urban mobility by reducing the need to travel and the distance and time required to move around.

This research evaluated the coverage offered by the facilities system in the city of Manizales in Colombia, a city that, like most Latin American cities, has a high concentration of its main urban activities in very established and developed economic centers in the urban centers.

The results show the concentration of the categories of facilities in recurring areas of the city: the mobility corridor between the CBD and the Cable Sector, with some variations according to the type of facility. Equivalent results are seen for the total cumulative opportunity potential model, and, with the varied opportunity model, it is established that the city has an important level of diversity in the proximity coverage of the facilities considered.

The peripheries of the city are the areas with the least access to services with the established conditions and it is these areas that concentrate the majority of the population of the lower socioeconomic strata in Manizales, causing the lower income population to have to invest more time and/or money to access the city's opportunities.

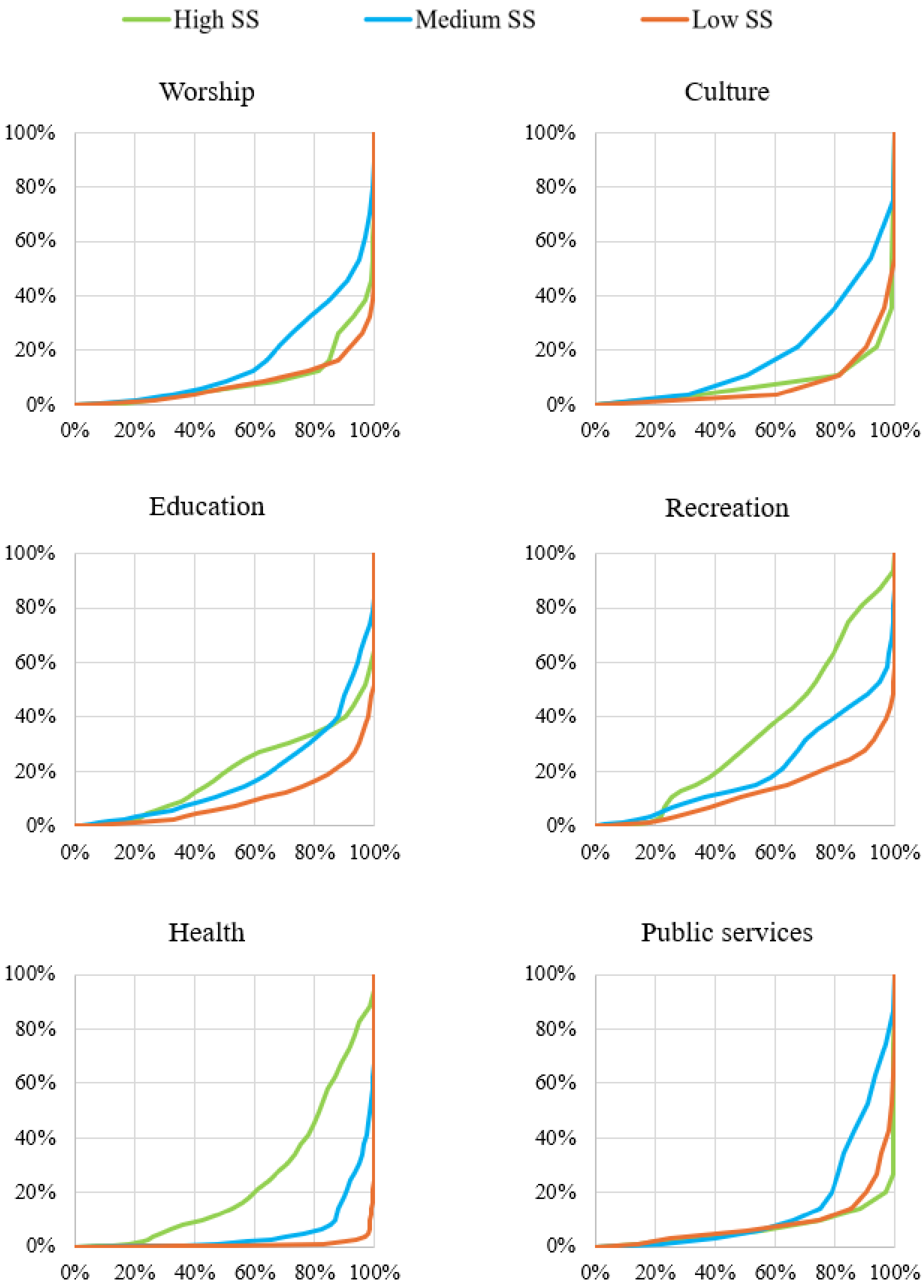

Figure 6. Coverage curves by Socioeconomic Strata (SS). The horizontal axis represents the percentage of the population, while the vertical axis represents the percentage of services of a given type that have been reached in relation to the total. Own elaboration.

This analysis is a planning tool as a base information to know the state of the spatial-temporal distribution of the city's main facilities, to advance in the city in an approach of decentralization of activities and polycentric development.

Cities require urban decision making that consolidates the decentralization of services and urban activity, bringing the diversity of amenities necessary for subsistence to each neighborhood, generating public policies of proximity that favor the conditions to encourage urban modal change that will allow moving towards mobility conditions with less social, economic, spatial and environmental impacts.

Acknowledgments
This article is part of the Master's program in Engineering - Infrastructure and Transportation Systems of the Universidad Nacional de Colombia. It is part of the research entitled: "Methodological proposal for the Social Cost Benefit Analysis given the implementation of sustainable transport modes in an urban area," Hermes Code: 62538.

We thank the members of the Sustainable Mobility Research Group (GIMS) and the Faculty of Engineering and Architecture for their support in the development of this research.

References

Alcaldía de Manizales. (2017) “Plan Maestro de Movilidad de Manizales”. At: https://www.infimanizales.com/wp-content/uploads/2018/06/Plan-Maestro-de-Movilidad-Manizales-PDF.pdf (Accessed: 01 August 2024).

Arellana, J. *et al.* (2021) 'Walk this way: Pedestrian accessibility and equity in Barranquilla and Soledad, Colombia,' *Research in Transportation Economics*, 86, p. 101024. https://doi.org/10.1016/j.retrec.2020.101024.

Aristizábal, J.E., Sarache, W. and Escobar, D.A. (2023) 'Spatial regression model of urban walkability under the 15-Minute City approach,' *GeoJournal of Tourism and Geosites*, 49(3), pp. 1037–1045. https://doi.org/10.30892/gtg.49319-1103.

Bannaga, S.E.I. (2018) 'Revitalization of Greater Khartoum urban transportation system,' *Future Cities and Environment*, 4(1). https://doi.org/10.5334/fce.2.

Bao, W.-W. *et al.* (2022) 'Exposure to road traffic noise and behavioral problems in Chinese schoolchildren: A cross-sectional study,' *The Science of the Total Environment*, 837, p. 155806. https://doi.org/10.1016/j.scitotenv.2022.155806.

Chan, O.F. *et al.* (2022) 'Neighborhood built environments and cognition in later life,' *Aging & Mental Health*, 27(3), pp. 466–474. https://doi.org/10.1080/13607863.2022.2046697.

Chen, H. *et al.* (2022) 'Mixed land use levels in rural settlements and their influencing factors: a case study of Pingba village in Chongqing, China,' *International Journal of Environmental Research and Public Health*, 19(10), p. 5845. https://doi.org/10.3390/ijerph19105845.

Desmond, M., Gershenson, C. and Kiviat, B. (2015) 'Forced Relocation and Residential Instability among Urban Renters,' *Social Service Review*, 89(2), pp. 227–262. https://doi.org/10.1086/681091.

Dureau, F. *et al.* (2013) 'Cambios urbanos, transporte masivo y desigualdades socio-territoriales en unos barrios del occidente de Bogotá*,' *Cuadernos De Vivienda Y Urbanismo*, 6(11), pp. 44–67. https://doi.org/10.11144/javeriana.cvu6-11.cutm.

Escobar, D., Sarache, W. and Jiménez-Riaño, E. (2022) 'The impact of a new aerial cable-car project on accessibility and CO2 emissions considering socioeconomic stratum. A case study in Colombia,' *Journal of Cleaner Production*, 340, p. 130802. https://doi.org/10.1016/j.jclepro.2022.130802.

Escobar D., Montoya J., and Moncada C. (2024). 'Territorial accessibility and peace promotion: an approach through the development of the road infrastructure network, ' *Norwegian Journal of Development of the International Science*, 136. https://doi.org/10.5281/zenodo.12798915.

Elldér, E., Haugen, K. and Vilhelmson, B. (2020) 'When local access matters: A detailed analysis of place, neighbourhood amenities and travel choice,' *Urban Studies*, 59(1), pp. 120–139. https://doi.org/10.1177/0042098020951001.

Fainstein, S.S. (2013) 'The just city,' *International Journal of Urban Sciences*, 18(1), pp. 1–18. https://doi.org/10.1080/12265934.2013.834643.

Ferrer-Ortiz, C. *et al.* (2022) 'Barcelona under the 15-Minute City Lens: Mapping the Accessibility and Proximity Potential Based on Pedestrian Travel Times,' *Smart Cities*, 5(1), pp. 146–161. https://doi.org/10.3390/smartcities5010010.

Finlay, J. *et al.* (2023) 'Neighborhood Built Environments and Health in Later Life: A literature review,' *Journal of Aging and Health* [Preprint]. https://doi.org/10.1177/08982643231217776.

Gilbert, A. (2004) 'Helping the poor through housing subsidies: lessons from Chile, Colombia and South Africa,' *Habitat International*, 28(1), pp. 13–40. https://doi.org/10.1016/s0197-3975(02)00070-x.

Hsu, W.-T. and Zhang, H. (2014) 'The fundamental law of highway congestion revisited: Evidence from national expressways in Japan,' *Journal of Urban Economics*, 81, pp. 65–76. https://doi.org/10.1016/j.jue.2014.02.002.

Jia, P. *et al.* (2020) 'Land use mix in the neighbourhood and childhood obesity,' *Obesity Reviews*, 22(S1). https://doi.org/10.1111/obr.13098.

Klanjčić, M. *et al.* (2022) 'Identifying urban features for vulnerable road user safety in Europe,' *EPJ Data Science*, 11(1). https://doi.org/10.1140/epjds/s13688-022-00339-5.

Laguecir, A. and Hudson, B.A. (2024) 'Too poor to get social housing: Accounting and structural stigmatisation of the poor,' Critical Perspectives on Accounting, 100, p. 102757. https://doi.org/10.1016/j.cpa.2024.102757.

Levine, J. et al. (2012) 'Does accessibility require density or speed?,' Journal of the American Planning Association, 78(2), pp. 157–172. https://doi.org/10.1080/01944363.2012.677119.

Li, Q. *et al.* (2022) 'Can mixed land use reduce CO2 emissions? A case study of 268 Chinese cities,' *Sustainability*, 14(22), p. 15117. https://doi.org/10.3390/su142215117.
Frenzel, M.P.L. and Casares, M. (2023) 'Infraestructura verde y espacios verdes públicos. Reflexiones desde el paisaje en el sistema metropolitano de Tucumán, Argentina,' *Ciudades*, (26), pp. 99-122. https://doi.org/10.24197/ciudades.26.2023.99-122.
Manaugh, K. and Kreider, T. (2013) 'What is mixed use? Presenting an interaction method for measuring land use mix,' *Journal of Transport and Land Use*, 6(1), pp. 63–72. https://doi.org/10.5198/jtlu.v6i1.291.
Marín-Cots, P. and Palomares-Pastor, M. (2020) 'En un entorno de 15 minutos. Hacia la Ciudad de Proximidad, y su relación con el Covid-19 y la Crisis Climática: el caso de Málaga,' *Ciudad Y Territorio Estudios Territoriales*. https://doi.org/10.37230/cytet.2020.205.13.3.
Moreno, C. *et al.* (2021) 'Introducing the "15-Minute City": Sustainability, resilience, and place Identity in future Post-Pandemic Cities,' *Smart Cities*, 4(1), pp. 93–111. https://doi.org/10.3390/smartcities4010006.
Moreno, J.R. (2020) 'Deconstruir el 'efecto barrio' desde una perspectiva comparada y su implicación criminológica en el sur global,' *Delito Y Sociedad. Revista De Ciencias Sociales*, (50), p. e0016. https://doi.org/10.14409/dys.2020.50.e0016.
Mouratidis, K. (2018) 'Built environment and social well-being: How does urban form affect social life and personal relationships?,' *Cities*, 74, pp. 7–20. https://doi.org/10.1016/j.cities.2017.10.020.
Mouratidis, K. (2024) 'Time to challenge the 15-minute city: Seven pitfalls for sustainability, equity, livability, and spatial analysis,' *Cities*, 153, p. 105274. https://doi.org/10.1016/j.cities.2024.105274.
Seong, E.Y., Lee, N.H. and Choi, C.G. (2021) 'Relationship between Land Use Mix and Walking Choice in High-Density Cities: A Review of Walking in Seoul, South Korea,' *Sustainability*, 13(2), p. 810. https://doi.org/10.3390/su13020810.
Shekfa, L. and Ahmed, K.G. (2022) 'The other side of the urban densification 'Coin': impacts on social sustainability in redeveloped urban sprawled communities in United Arab Emirates,' *Future Cities and Environment*, 8(1). https://doi.org/10.5334/fce.155.
Sierra Muñoz, J. *et al.* (2024) 'Why do we rely on cars? Car dependence assessment and dimensions from a systematic literature review,' *European Transport Research Review*, 16(1). https://doi.org/10.1186/s12544-024-00639-z.
Suárez-Celis, J. *et al.* (2024) 'Calculation of average global accessibility conditions for bicycles considering the longitudinal road slope: case study Ibagué – Colombia,' *Future Cities and Environment*, 10(1). https://doi.org/10.5334/fce.309.
Swapan, M.S.H., Aktar, S. and Maher, J. (2024) 'Revisiting Spatial Justice and Urban Parks in the Post-COVID-19 Era: A Systematic Literature review,' *Sustainability*, 16(10), p. 3929. https://doi.org/10.3390/su16103929.
Tiznado-Aitken, I. *et al.* (2023) 'Unequal periurban mobility: Travel patterns, modal choices and urban core dependence in Latin America,' *Habitat International*, 133, p. 102752. https://doi.org/10.1016/j.habitatint.2023.102752.
Urry, J. (2004) 'The 'System' of automobility,' *Theory Culture & Society*, 21(4–5), pp. 25–39. https://doi.org/10.1177/0263276404046059.
Villanueva, K. *et al.* (2016) 'Can the Neighborhood Built Environment Make a Difference in Children's Development? Building the Research Agenda to Create Evidence for Place-Based Children's Policy,' *Academic Pediatrics*, 16(1), pp. 10–19. https://doi.org/10.1016/j.acap.2015.09.006.
Waddell, P. (2002) 'UrbanSIM: Modeling Urban Development for land use, transportation, and environmental planning,' *Journal of the American Planning Association*, 68(3), pp. 297–314. https://doi.org/10.1080/01944360208976274.
Weiss, D.J. *et al.* (2018) 'A global map of travel time to cities to assess inequalities in accessibility in 2015,' *Nature*, 553(7688), pp. 333–336. https://doi.org/10.1038/nature25181.
Wright Wendel, H. E., Zarger, R. K., & Mihelcic, J. R. (2012), "Accessibility and usability: Green space preferences, perceptions, and barriers in a rapidly urbanizing city in Latin America", *Landscape and Urban Planning*, 107(3), pp. 272–282. https://doi.org/10.1016/j.landurbplan.2012.06.003.
Wu, H. *et al.* (2021) 'Urban access across the globe: an international comparison of different transport modes,' *Npj Urban Sustainability*, 1(1). https://doi.org/10.1038/s42949-021-00020-2.
Wu, H. and Levinson, D. (2020) 'Unifying access,' *Transportation Research Part D Transport and Environment*, 83, p. 102355. https://doi.org/10.1016/j.trd.2020.102355.
Wu, X. *et al.* (2022) 'Long-term characterization of roadside air pollutants in urban Beijing and associated public health implications,' *Environmental Research*, 212, p. 113277. https://doi.org/10.1016/j.envres.2022.113277.

Young, I. M. (1990) *Justice and the politics of difference*. https://doi.org/10.2307/j.ctvcm4g4q.
Zhang, Y. *et al.* (2024) 'Counterfactual mobility network embedding reveals prevalent accessibility gaps in U.S. cities,' *Humanities and Social Sciences Communications*, 11(1). https://doi.org/10.1057/s41599-023-02570-5.
Zumelzu-Scheel, A. (2016) 'Forma urbana y sostenibilidad: pasado, presente y desafíos. Una revisión,' *AUS*, (20), pp. 77–85. https://doi.org/10.4206/aus.2016.n20-12.