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Utility-based accessibility to evaluate transport policies in Latin America

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Abstract

There is now a long tradition of accessibility research in Latin American cities, with an increasingly rich set of frameworks and methods from a distributional perspective. Despite such a positive outlook, most accessibility metrics deployed in research and practice do not consider the dimension of (dis)utility, which resonates more clearly with mainstream transport decision-making and planning. This paper seeks to contribute to debates about the use of utility-based measures as inputs for accessibility assessment of transport infrastructure investments in the Global South using discrete choice modeling and its potential as a bridging language between socially nuanced and economics-driven transport planning practices. This paper uses mixed revealed preferences and stated preferences data collected in Bogotá, Colombia. Then, it uses a logsum accessibility metric to estimate the differentiated impact of a set of infrastructure interventions on the accessibility of residents with different income levels and other socioeconomic conditions for accessing opportunities in the city. Particularly, the logsum accessibility metric analyses future innovations and structural additions to Bogotá public transport networks reflecting their effect on the accessibility and consumer surplus in the next 20 years. The proposed approach captures the benefits derived from the opportunity locations and transport infrastructure improvements, which has relevance for debates about transport policy and practice in this and similar urban contexts in the Global South. These accessibility gains could be assigned a monetary value to include in project cost-benefit assessments.

Keywords: logsum; evaluation; Latin America

1. Introduction

The slow progress in adopting an accessibility-oriented approach in policy and decision-making, particularly in Latin American urban contexts, has widened inequalities linked with mobility and caused declines in the quality of life of citizens (Vecchio et al. 2020). This is partly due to a persistent utilitarian approach to transport planning and decision-making that tends to prioritize the ‘average’ user as a reflection of the population’s travel needs (Oviedo and Nieto-Combariza 2021) as well as a lack of consensus on accessibility measures (Handy 2020). Accessibility is often defined and operationalized in diverse ways with several meanings. Accessibility-oriented policies can only become a reality if the concept is easy to interpret for decision-makers and can be estimated with available data and tools to analyze land use and transport interaction (Geurs and van Wee 2004).

Several studies have contributed to quantifying different forms of accessibility measures. Three accessibility measures are commonly found in the literature which are well documented and explained: contour, gravity-based, and utility-based measures. The first two measurements are popular in geography and urban planning studies due to their easiness of calculation. However, both measures assume that all opportunities are equally desirable, regardless of the transport mode used and the socioeconomic characteristics of the commuter. These are important limitations considering the complex environments for urban mobility in which these choices are made.
Utility-based measures can overcome some of these limitations by incorporating additional elements into the analysis of accessibility. These measures can be estimated through discrete choice models, which are based on Random Utility Maximization (RUM) behavioral theory, allowing us to estimate consumer surplus using the logsum method. This approach allows for the evaluation of the maximum utility perceived in a travel choice situation considering the availability of transport alternatives, the combination modes in multimodal trips, and the individual’s preferences, indicating the desirability of the full choice set.

This paper aims to estimate a comprehensive utility-based accessibility indicator for Bogotá, Colombia, using a multinomial logit model, estimated by combining revealed preferences (RP) and stated preferences (SP) data. The utility-based accessibility approach allows researchers to quantify the welfare consequences of accessibility changes in the study area due to transport investments in hypothetical scenarios, which consider a set of transport projects in line with the plans for Bogotá. This research seeks to contribute to the literature by testing and implementing a more sophisticated accessibility indicator for Bogotá, using a metric that focuses on understanding people’s benefits to reach their diverse destinations and allows expressing accessibility in economic terms, considering a transport demand function. Such a measure has the potential to make positive contributions to planning and economic project appraisals by using a utility-based accessibility measure to estimate welfare. The analysis seeks to spark reflections about the subjective dimension of accessibility and the differences between (dis)advantage and utility.

2. State of art

A limited number of studies have explored the links between accessibility using utility-based measures. The utility-based accessibility is founded on microeconomic theory and overcomes some limitations of traditional accessibility measures because it captures the heterogeneity of users’ preferences, perceptions, and sociodemographic characteristics (Geurs and van Wee 2004). It is possible to assert the degree to which accessibility is influenced by individual perceptions (Pot et al. 2021). Such type of metrics for accessibility has not been used frequently in the Latin American context.

The definition of utility-based accessibility is based on the desirability of transport alternatives (Ben-Akiva and Lerman 1985). Accessibility is measured at the individual level considering commuters’ characteristics and modal attributes (Banister and Berechman 2001). Therefore, in a standard multinomial logit (MNL) model, it is possible to use the logsum component as an accessibility measure, which corresponds to the natural logarithm of the denominator of the MNL probability.

The logsum can be understood as the expected worth of a set of alternatives or a measurement of the maximum utility expected from the choice set. If accessibility is interpreted as an outcome of a set of transport choices, the logsum term can be understood as a utility-based measure of accessibility (Geurs and van Wee 2004) depending on the demand functions estimated in the mode choice models. As the demand functions depend on the perceptions and preferences of the choice-maker, it has a subjective valuation component that drives the expected utility. Then, as the logsum represents the maximum expected utility, the higher the logsum, the higher the accessibility perceived by the traveler.

Few empirical studies capture the heterogeneities in accessibility regarding sociodemographic characteristics. For example, Ziemke et al. (2018) compared household-based and utility-based accessibilities. They found that the latter needs much lower input data requirements and has advantages in terms of interpretability. Lu et al. (2014) present a utility-based measurement of accessibility to estimate the effects of different forms of information and communication technologies on accessibility. Nassir et al. (2016) capture public transport passengers’ behavior and their subjective perceptions of travel costs to measure the accessibility of the public transport network in Brisbane, Australia. In Denizli, Turkey, Gulhan et al. (2013) evaluate a utility-based accessibility indicator as a new parameter to support the decision-making process for investments and regulations, founding a more effective system in terms of accessibility.

In addition to the state of the art of utility-based approach to accessibility, it is important to put consumer surplus into context. In welfare economics, the consumer surplus is measured in monetary terms, by the benefits received in a choice situation (i.e., the decision-maker chooses the alternative that provides the greatest utility). It is worth highlighting that the willingness to pay might not be equal to what people pay. Hence, the consumer surplus is linked
to the willingness to pay for a good or service. It reflects the value individuals give to the good or service associated with the level of welfare they obtain by accessing it.

Examining accessibility in terms of welfare gains has an additional practical value since economic evaluation is the standard method to evaluate policy options and alternatives for public investment, which the accessibility literature has identified as a necessary area where gaps between theory and practice need to be narrowed. This leads to an explicit need to express accessibility effects in monetary terms (van Wee 2016). Utility-based measures capture the valuation of accessibility by individuals, providing a valuable basis for cost-benefit analysis or multi-criteria analysis evaluations of transport investments (Geurs and van Wee 2004).

3. Case study

The travel unequal patterns in Bogotá imply an unequal distribution of accessibility levels, particularly for public transport users (86%), who mainly belong to the lower socioeconomic categories of the city (socioeconomic strata, SES, 1 to 3) and live on the periphery. SES is a residential land classification between 1 and 6, where 1 corresponds to the poorest zones and 6 to the wealthiest, and it is usually used as a proxy for the average household income level (Cantillo-García et al. 2019). These gaps have existed for many years in the city and, in some cases, they have worsened because lower-income populations cannot afford housing inside Bogotá and must therefore move to neighboring municipalities.

Accessibility in Bogotá has been previously studied by a growing number of urban and transport researchers over the years (Arellana et al. 2021; Guzman et al. 2018; Guzman et al. 2017b; Guzman and Oviedo 2018) highlighting the inequalities described above through different mechanisms. Most of these studies used potential accessibility and contour measures, which are better suited as diagnosis instruments, and are difficult to compare in certain contexts. Also, these measures do not necessarily provide a direct way to estimate changes in accessibility for changing conditions of land use and transport systems.

In this context, the national and local governments decided to launch an ambitious transport infrastructure plan for the year 2035, which consists of million-dollar investments in the construction and expansion of regional roads, improvement of access roads to Bogotá, and the construction of more cable cars and BRT corridors, the first two metro lines and regional trains. However, this plan is still largely focused on enabling mobility rather than access. Given the scale and purpose of the proposed plan, this case presents an appropriate testing ground for the use of utility-based accessibility measures.

4. Methodology

To estimate the accessibility measure, we use the mode choice utility functions estimated in Guzman et al. (2021). The MNL model considers the utility of using a particular transport mode alternative, given trip attributes and choice-maker characteristics. Then, the discrete choice model is linked to the consumer surplus concept (Niemeier 1997). It allows estimating the expected net benefits of transport users by monetizing consumer surplus using the cost parameter and subjective values of time from the choice model. Travel costs and travel times for each scenario are estimated using a four-stage classic transport.

From the perspective of welfare transport evaluation, investments in infrastructure and public transport services reduce generalized travel costs. In addition, there may be benefits for both existing and new users attracted by this cost reduction. Consumer surplus is easy to estimate when the demand function is assumed to be linear. The demand function in Figure 1 intersects the marginal cost functions (Sx). The current supply function (S0) is improved by implementing policies such as expanding the network’s capacity or building new infrastructure. In this case, the supply curve moves downward to S1, and the demand curve intersects in a new equilibrium price P1, lower than P0, resulting in a demand increase from Q0 to Q1. The benefits received by existing and new users together, between S0 and S1, are
equal to the shaded polygon in Figure 2, whose value is usually calculated using the Rule of Half (Tressider et al. 1968). This net benefit or welfare is called the consumer surplus.

However, travel demand functions are not usually linear. One of the most recognized approaches to evaluating travel demand is discrete choice modeling techniques (Ortúzar and Willumsen 2011). Discrete choice models assess the probability of selecting one alternative among a set of finite available options, considering choice-maker characteristics and attributes regarding the alternatives and the context. These methods also provide a robust framework to estimate substitution patterns such as willingness to pay and welfare change measures, allowing for the assessment of distributional effects by capturing preference heterogeneity considering different population segments. To observe the distributional effects, we disaggregated the results by gender, occupation, and income level.

![Graph of Consumer Surplus](image)

**Fig. 1. Consumer surplus**

Grounded on the RUM economic theory, discrete choice modeling methods assume that the choice-maker is a rational agent that selects the alternative that maximizes its utility. The concept of utility can be associated with the satisfaction or benefits that the individual obtains by accessing the good or service selected. The systematic utility is usually represented as a linear combination of observed attributes and a set of parameters to estimate, but it can assume diverse structures. Therefore, the expected consumer surplus might be calculated using Equation 1 (Train 2009).

\[
E(CS_i) = \frac{1}{\alpha_i} E\left[ \max_j (V_{ij} + \epsilon_{ij}) \right]
\] (1)

Under multinomial logit assumptions, \(\epsilon_{ij}\) is assumed independent and identically (IID) Gumbel distributed, utility is linear in income, and the probability of choosing alternative \(j\) from a set of \(N\) available alternatives. It can be demonstrated that the expected value of the maximum utility perceived by the choice-maker can be expressed as in Equation 2, a formulation known as the logsum, where \(C\) is an unknown constant related to the fact that the absolute utility cannot be measured (Williams 1977). Assuming that \(C\) is constant across scenarios, Equation 2 might be used to evaluate changes in consumer surplus by estimating the difference as seen in Equation 3. Note that this formulation allows estimating the net consumer surplus change between scenarios, represented as the shaded polygon in Figure 1.

\[
E(CS_i) = \frac{1}{\alpha_i} \ln \left( \sum_j e^{V_{ij}} \right) + C
\] (2)

\[
\Delta E(CS_i) = \frac{1}{\alpha_i} \left[ \ln \left( \sum_j e^{V_{ij}^{after}} \right) - \ln \left( \sum_j e^{V_{ij}^{before}} \right) \right]
\] (3)
The CS estimated through logsum differences in monetary terms refers to the amount needed to compensate individuals for enduring the policy change under evaluation (Zhao et al. 2012). Regarding the marginal utility of income ($\alpha_i$), it might be estimated as the negative of the parameter of a cost variable included in the systematic utility of the discrete choice model.

The logarithm in Equation 4 denotes the expected benefit for an individual in an MNL formulation and it is known as the logsum. In the context of a transport choice, the logsum can be used as a utility-based accessibility measure, since it represents the desirability of the complete set of available alternatives (Ben-Akiva and Lerman 1985; Geurs and van Wee 2004). Equation 4 shows the logsum as a measure of accessibility ($A_i$), where $\mu$ is the scale factor associated with $\epsilon_{ij}$ in the logit framework, usually assumed as 1 for identification purposes. Note that $A_i$ is the maximum expected utility of the choice situation, and it can be transformed into monetary units by dividing it by the cost parameter. Individual accessibility can be aggregated among groups, either spatially or by population segments, by calculating the weighted mean, where the weights reflect the proportion of trips made during the studied period by individuals with the same representative utility (Zhao et al. 2012).

\[
A_i = \frac{1}{\mu} \ln \left( \sum_j e^{\mu \epsilon_{ij}} \right)
\] (4)

The utility-based accessibility can also be considered a measure of ‘experienced’ accessibility since it is calculated with information from the actual trips made by the individuals and considers commuter preferences. Also, the utility-based accessibility measure has the same scale and units of the utility functions. Even though it is strictly an ordinal scale, the RUM framework allows for relaxing this requirement and treating it as a cardinal variable for practical purposes (Batley 2008).

Note that the utilities and the accessibility measure can also take negative values. On one side, this is because only a portion of the utility is observed. Moreover, if the transport demand is assumed to be a derived demand and the utility function is specified to capture the ‘disutility’ experienced by the commuter, the utility domain could include negative values. It is important to mention that one specific value of utility-based accessibility provides little information as the real scale and magnitude of the utility are unknown. However, it can be used to compare the experienced accessibility between population segments, assuming that the unobserved component of the utility is equal and considering that a higher measure means higher accessibility.

Two simulated scenarios are studied and processed to estimate the accessibility changes and consumer surplus based on the 2019 baseline scenario. These scenarios represent the projected infrastructure building plans in the study area in two-time horizons. The scenarios considered in this research and their characteristics are summarized below:

- **Baseline scenario 2019.** There is 114.4 km of BRT corridors, covering just Bogotá and Soacha (a southern neighboring municipality) and one cable car. Bogotá’s road network comprises 13,970 lane-km with high levels of congestion. It is worth saying that currently in the study area, public transport only includes the BRT system and regular buses.
- **Scenario 2028:** The first metro line comes into operation. It includes two new BRT corridors (+24.4 km), the western regional train, and four new cable cars. In terms of new road infrastructure, there is a western perimeter road, an improvement of accesses to the north of the city, and several corridors to the south of the city, as is shown in Figure 3 left.
- **Scenario 2035:** In addition to the projects in the previous scenario, public transport, and road infrastructure projects are included, such as the green corridor of Carrera 7 (the most emblematic street in the city), the second metro line, more cable cars, the regional train of the city north and another expansion of the northern road accesses.
To evaluate these scenarios, we estimated travel demand for the horizon years. Since this accessibility approach is part of a project to support local and regional governments' decision-making and planning processes, we estimated trip generation and attractions using an updated version of Bogotá’s Land-Use and Transport Interaction model (Guzman 2019). The final travel demand estimation is 18.2 million trips/day in 2028 and 19.7 million trips/day by 2035. We then evaluate consumer surplus and distributional effects by population segment and zone.

The CS differences between scenarios were estimated and aggregated in two ways by averaging by population segments and by zone. It is relevant to mention that the availability of private modes corresponds to the reported vehicle ownership in the 2019 Household Travel Survey (HTS). In contrast, we determined the availability of the public transport alternatives (i.e., regular bus, BRT, metro, and train) using GIS procedures joining the origin zone and the availability of stations. Finally, cycling and walking are available for trips under 10 and 5 kilometers.

5. Results

The utility functions come from a multinomial logit model choice model calibrated using RP and SP data, implementing the data enrichment paradigm. The combined data approach allows the evaluation of preferences towards new alternatives (metro and train) through the SP component while capturing the current behavior of individuals with the RP part, reducing the bias associated with the hypothetical nature of the SP data. Our model includes the alternatives car, motorcycles, public transport, walking, and cycling. Note that metro and train are only available in the projected scenarios. Thus, the combined data model allows for estimating the utility-based accessibility in the projected scenarios. The utility functions in the model include systematic taste variations to capture preference heterogeneity. Specifically, the model includes interactions of the constant with gender for public transport alternatives, travel cost with occupation and household size, and travel time with SES. The general form of the systematic utility functions $V$ perceived by individual $i$ for alternative $j$ is described as follows:

$$V_j = ASC_j + (\beta c + \beta c_{NO} * NO + \beta c_{HS} * HS) * C_j + (\beta t + \beta t_{LI} * LI + \beta t_{HI} * HI) * T_j + \beta W_j * W * TP \quad (5)$$

Where $\beta$ is a set of parameters to estimate. $ASC$ is the alternative specific constant. $NO$ is a dummy that takes the value of 1 if the individual does not work or study (i.e., non-occupied). $HS$ is a dummy that takes the value of 1 if the household has more than three inhabitants. $LI$ and $HI$ are dummy variables that take the value of 1 if the individual belongs to a low- or high-income level respectively. $W$ is a dummy that takes the value of 1 if the individual is female. $TP$ is a dummy that takes the value of 1 if the alternative is public transport. Ultimately, $C_j$ and $T_j$ are the cost and travel times. This demand function allows disaggregating results considering systematic taste variations according to the transport mode used, gender, occupation, household size, and income level. The latter was categorized into three levels: low income corresponds to the lowest 20%, and high income to the top 20% according to the city’s per capita household income distribution. We also divided the sample into occupied (i.e., workers and students) and non-occupied. Table 1 shows the estimation results for the mixed SP-RP mode choice model used in the analysis, details of the model can be found in the paper by Guzman et al., (2021).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mixed SP-RP model Estimates</th>
<th>t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASC Train (SP)</td>
<td>0.820</td>
<td>4.66</td>
</tr>
<tr>
<td>ASC Metro (SP)</td>
<td>1.919</td>
<td>8.37</td>
</tr>
<tr>
<td>ASC Motorcycle (RP)</td>
<td>-1.304</td>
<td>-12.26</td>
</tr>
<tr>
<td>ASC BRT (RP)</td>
<td>-0.925</td>
<td>-10.48</td>
</tr>
<tr>
<td>ASC Bicycle (RP)</td>
<td>-2.424</td>
<td>-22.24</td>
</tr>
<tr>
<td>ASC Walking (RP)</td>
<td>0.272</td>
<td>3.02</td>
</tr>
<tr>
<td>Cost (SP)</td>
<td>-0.059</td>
<td>-3.61</td>
</tr>
<tr>
<td>Cost (RP)</td>
<td>-0.141</td>
<td>-8.97</td>
</tr>
<tr>
<td>Cost interaction: non-occupied</td>
<td>-0.035</td>
<td>-1.89</td>
</tr>
<tr>
<td>Cost interaction: Household size</td>
<td>-0.055</td>
<td>-4.48</td>
</tr>
<tr>
<td>Time</td>
<td>-0.024</td>
<td>-13.11</td>
</tr>
<tr>
<td>Time interaction: Low-income (SP)</td>
<td>0.012</td>
<td>8.59</td>
</tr>
<tr>
<td>Time interaction: Low-income (RP)</td>
<td>0.001</td>
<td>0.55</td>
</tr>
</tbody>
</table>
The cost and travel time attributes for the scenarios come from a four-step transport model calibrated to reproduce the conditions observed for the study area in 2019. We also used a database from a large OD survey collected in Bogotá in 2019, which is representative of Bogotá’s population and the daily travel demand. Using these tools and data, we estimated the utility-based accessibility (logsum) for each trip included in the 2019 HTS. Then, the CS between scenarios was estimated and aggregated in two ways: by population segments and by zone.

Considering the above, Table 2 includes the subjective values of time (SVT) by income group and occupation according to the systematic variations for travel time and cost considered in the MNL formulation. Note that the SVT can be seen as the willingness to pay for a one-unit travel time-saving. The SVT increases with income and for those occupied. Further information regarding the choice model and the data can be found in Guzman et al. (2021).

Table 2. Subjective values of time (SVT) (1 USD = 3,280 COP IN 2019)

<table>
<thead>
<tr>
<th>Segment</th>
<th>Income group</th>
<th>Occupation</th>
<th>SVT (USD/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low income</td>
<td>Non-occupied</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Occupied</td>
<td>1.22</td>
</tr>
<tr>
<td></td>
<td>Medium income</td>
<td>Non-occupied</td>
<td>2.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Occupied</td>
<td>2.61</td>
</tr>
<tr>
<td></td>
<td>High income</td>
<td>Non-occupied</td>
<td>4.58</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Occupied</td>
<td>5.58</td>
</tr>
</tbody>
</table>

The interpretation of the utility-based accessibility measure poses various challenges. First, the units might be considered a subjective scale to measure the utility experienced by the choice maker, making it difficult to interpret and communicate. This is overcome by transforming the utils into monetary terms by dividing the utility value by the associated attribute coefficient. In this case, the result can be interpreted as a measure of the total cost experienced by the choice-maker in a given situation.

Second, as there is an unobserved component in the utility functions, it is only possible to estimate a portion of the total desirability of the choice set. For these reasons, the unique value of utility-based accessibility provides limited information. Comparing measures between population segments requires the assumption that the unobserved utility is equal between the segments under evaluation. This assumption can be relaxed when evaluating consumer surplus and policy implications among different scenarios, in which case it is less strong to assume that this unobserved component remains equal across population segments (de Jong et al. 2007).

Considering the above, we evaluated CS changes between the baseline and the projected scenarios after the accessibility estimation. The CS change refers to the difference, in monetary terms, of the logsums from the scenarios under comparison. It is relevant to mention that to calculate the average consumer surplus, we performed a weighted mean of the surplus experienced in each trip from the 2019 HTS, where the weights are the number of daily trips made by individuals with the same representative utility, that is, from the same population segment. The average surplus is multiplied by the daily trips to obtain the aggregate CS change.
Results indicate that the new transport investment evaluated in the projected scenarios improves the consumer surplus associated with daily accessibility in Bogotá. The average logsum per trip in 2019 was 1.89 USD, decreasing by 13% and 24% for 2028 and 2035, respectively. As the logsum in monetary terms indicates a cost, the decrease suggests a welfare improvement. Considering that the number of daily trips in 2019, 2028, and 2035 is 15.4, 18.2, and 19.7 million respectively, the aggregate consumer surplus change in a typical day in 2028 concerning 2019 is around 4.5 million USD, and in 2035 compared to 2028 is 4.0 million USD.

To evaluate distributional effects by population segments, we disaggregated the consumer surplus results by sex, occupation, and income level. These results are summarized in Figure 2, which exposes the consumer surplus change between the projected scenarios compared to the baseline scenario. Most segments are better off on average in the projected scenarios compared to the baseline, except for wealthy females, and wealthy occupied males in 2028, which experience a negative consumer surplus change. That is, high-income females experience their trips to be more expensive, in 2028 and 2035 compared to the baseline. In other words, the desirability of their trips is lower in the projected scenarios.

Results also suggest differences in income level and occupation. Higher benefits are experienced by low- and medium-income individuals, as well as by male-occupied commuters. This could be because the new infrastructure aims to improve the public transport system with new BRT, metro, and train corridors connecting Bogotá with neighboring municipalities to the north and west, where a sizeable proportion of the low-income population live. However, the road network does not have important improvements. Hence, the level of service of private vehicles improves at a smaller scale compared to public transport users. This could affect high-income users, which rely more heavily on private vehicles, as 41% of their trips are made by car, compared to 17% for medium-income and 4% for low-income. Furthermore, the proportion of trips made by public transport is 31%, 34%, and 25% for low-, medium- and high-income segments, while in the case of walking and cycling is 60%, 44%, and 34% respectively, according to Bogotá’s 2019 HTS.

Consumer surplus results also align with the SVT presented in Table 2. As the SVT increases with income, the individuals experience lower welfare in their daily mobility, even though higher-income segments make shorter trips. In fact, in Bogotá, according to the 2019 HTS, the average distance traveled by high-income users in public transport is around 10 km, while for medium- and low-income is 11.3 and 12.2 km, respectively. In contrast, for car trips, the average distances are 7.9, 8.5, and 9.5 km for high-, medium-, and low-income segments, while for walking trips the average distances are 2.8, 3.4, and 3.7 km, respectively.

![Fig. 2. Average consumer surplus by trip](image-url)
As mentioned in the accessibility analysis, higher SVT implies a higher disutility experienced in trips of the same length, compared to users with lower SVT. In other words, one unit of travel time saved by a higher-income user has a higher valuation in monetary terms. This means that the utility-based accessibility and welfare analysis estimated with logsum methods have a subjective component as it strongly depends on individual preferences. Therefore, in our analysis, the accessibility experienced by higher-income users is lower despite making shorter trips. If these issues are not considered, one might come to the wrong conclusion that high-income users have more transport disadvantages. Moreover, as with other accessibility frameworks, utility-based measures also rely heavily on travel patterns (origins and destinations), which define trip costs. Therefore, the perceived utility depends on where travel is.

The subjective nature of utility-based accessibility entails challenges when using these methods for project evaluation, especially when comparing benefits for different population segments. Although estimating consumer surplus might help capture the welfare changes in the context of transport policy evaluations, if the differences between preferences and subjective time valuations are not considered, it might lead to poor targeting of resources. This has implications for planning purposes, as it could lead to underestimating the benefits in low-income zones. We thus recommend complementing cost-benefit analysis by including evaluations using the accessibility appraisal for different population segments to minimize this bias.

Our analysis suggests that the higher disutility that higher-income commuters perceive translates into a perception of higher costs for even shorter trips. Higher availability of opportunities leads to a higher marginal disutility for every additional unit of travel cost. Furthermore, findings also suggest that welfare benefits for wealthier populations are lower in comparison to low-income users in the evaluated scenarios. As income grows and more people transition into the middle class and higher-income groups, it is expected that they perceive a disutility shift, therefore influencing population expectations of the transport system. This will be discussed further in the following section.

6. Conclusion

The proposed utility-based accessibility captures the benefits derived from the spatial distribution of opportunities and transport infrastructure improvements using discrete choice modeling. The estimations of accessibility and welfare measures depend on individual preferences that determine utility functions, adding a subjective dimension to the estimation of accessibility and controlling preferences and perceived disutility by different socioeconomic groups. Although in a transport mode choice situation travel cost and travel time are two determinant attributes, they are certainly not the only ones, nor do they have the same meaning and influence for all commuters.

The marginal utility of travel time tends to decrease with income (Guzman et al. 2021). That is, lower-income individuals are willing to accept higher travel times to save money. In this line, willingness to pay increases with income. This generates equality issues as limitations in the ability to pay for lower-income commuters force trade-offs between household location, travel costs, and travel times. In urban areas, these asymmetries result in lower-income population segments residing in deprived areas, usually far from the main opportunities, and experiencing higher travel times and lower accessibility to jobs and services, becoming trapped in a self-reinforcing cycle of disconnection and forced acceptance of increasing travel costs, which are reflected in the subjective value of time of poorer residents.

The approach based on logsum methods allows evaluation of a broader range of policy variables and scenarios than potential accessibility metrics since the flexibility of discrete choice modeling frameworks allows to specify any explanatory variable, as opposed to measures based on generalized costs (i.e., contour and gravitational accessibility measures), which are usually limited to travel time and cost. However, the subjective nature of many discrete choice experiments, especially when based on SP data or when evaluating new market contexts, might generate some bias, some of which could be overcome by complementing the SP with RP data through combined modeling techniques (Louviere et al. 2000). Moreover, the consistency of this framework with behavioral microeconomic theories, such as
RUM, allows the evaluation of a wider range of welfare implications. Accessibility gains converted into monetary values can be useful in the practice of CBA, and therefore, incorporating accessibility in transport planning and economic evaluation of projects, considering equality issues, can lead to prioritizing the accessibility approach over the traditional mobility approach. This is in the interest of policy- and decision-making, as the proposed methods could contribute to evaluating the social implications of transport, such as the links with social capital, subjective well-being, and quality of life.

The proposed approach has the potential to inform deeper distributional analyses grounded in more complex frameworks such as transport-related social, exclusion, which have only been explored qualitatively in the local context (Oviedo Hernandez and Titheridge 2016). Discrete choice models enable the consideration of variables associated with social exclusion and the restriction of mobility by factors other than time, cost, and comfort. These include fear of crime, perceptions of road safety, vulnerability to harassment and other forms of violence, discrimination, time poverty, care responsibilities, and other factors that have been identified in the literature as significant determinants of access but that as of yet have not been incorporated in traditional metrics. While this study shares these limitations, it also opens a path for further research that explores these variables in discrete choice models that can later be translated into accessibility assessments of transport interventions.

References


