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A choice experiment in Latin America

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Acronyms

BRT	Bus Rapid Transit
SES	Socioeconomic Stratum
TNC	Transportation Network Company
USA	United States of America
VMT	Vehicle Miles Travelled

Content

The potential for integration of ride-hailing with mass transit systems: A choice experiment in Latin America

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Abstract

As transportation alternatives facilitated by TNCs (Transportation Network Companies) have gained popularity around the world, research has increasingly focused on understanding their impacts on urban mobility, with several studies examining whether they are competing with public transit trips, increasing vehicle kilometers, or contributing to congestion. Recent policy discussions have turned to whether these services could also have positive benefits, such as complementing mass transit services as a first- and last-mile solution. Most research to date has focused on industrialized countries, with little work focusing on Global South cities. Seeking to fill significant evidence gaps on the impacts of ride-hailing on travel behavior, this paper builds on a stated preference survey in three large metropolitan areas in Latin America (Bogota, Medellin, and Mexico City) to evaluate the potential of introducing an integrated scheme of ride-hailing and mass transit. The scenario of the integrated scheme places ride-hailing as a filler of the first- and last-mile gap left by mass transit. We use discrete choice models and simulations to assess the potential for modal shifts under different pricing scenarios. Results suggest limited feasibility (or modal shifts) of an integrated system of ride-hailing with mass transit under the scenarios considered. Even with significant discounts on the integrated fare, for two of the three cases, the additional ridership would remain comparatively low. Nevertheless, this opens the door for considering other app-based mobility options operating under a sharing perspective and that can reduce operative costs in an integrated scheme.

JEL classification: J16, N76, 032

Keywords: Car ownership, Ride-hailing, Sustainability, Structural Equation Models SEM, Transportation Network Companies TNC

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1. Introduction

Ride-hailing services[1] emerged in major north American cities as a mobility solution more than a decade ago (Dudley et al., 2017) and are now a common transport mode available in major cities around the world. Also known as Transportation Network Companies (TNCs), the advent of these services has spawned several other app-based mobility innovations including, pooled ride-hailing (where several riders share the trip and the fare), micromobility (shared e-scooters and bikeshare systems), and delivery. In ride-hailing, payment is usually cashless and mediated through a cell phone application provided by a private TNC (e.g., Uber, Lyft). Apart from facilitating a way to hire, pay, and travel, digital ride-hailing platforms collect data about the trip and feedback from passengers and drivers regarding service quality and passenger behavior, creating an environment of perceived increased safety for both the driver and the rider (Sabogal-Cardona et al., 2021; Scholl et al., 2021b).

Deemed as a key disruptor of the urban transportation sector by practitioners and academics alike, ride-hailing began operations in the USA and then spread to virtually every other country in the world. In many countries, particularly in the Global South, where unregulated modes of transport are prevalent, this disruption has provided a new way of connecting users with drivers through technology. For example, in many Latin American urban areas, transportation provided by unregulated fleets of private vehicles in the peripheries of cities or during nighttime that have been organized as a word-of-mouth business are now facilitated through apps.

Ride-hailing services are now in operation in several Latin American countries, with a myriad of both international and homegrown TNCs. Probably the first of these companies operating in the region was EasyTaxi, which entered the Brazilian market in 2011. Today, the most popular ride-hailing applications are Didi and Uber, who launched their operations almost simultaneously in 2013 in Mexico City and then moved to capital cities in other countries. Services mediated by TNC platforms are relatively easy to use and are often perceived by users to be safer than conventional taxis and public transportation (Scholl et al., 2021b; Weber, 2019).

However, these services have also been at the center of policy debates questioning the extent to which they contribute to congestion, compete with more sustainable modes of transport such as public transit, walking or biking, or have adverse effects on jobs in the traditional taxi industry (Erhardt et al., 2019; Hall et al., 2018). In many countries in the region, these concerns have prompted regulators and policymakers to restrict or ban ride-hailing services, generating a complex environment for on-demand transport provision, and leading to repeated conflicts with competitors, governments and sometimes even users (Oviedo et al., 2021). While advocates of these services argue that they can complement public transit and help reducing car dependency (i.e., by improving first/last-mile connectivity to and from public transport), detractors contend that ride-hailing syphons demand from transit (Hall et al., 2018). More recently, some TNCs have begun working in tandem with taxi drivers as a strategy to both changing the position of their platforms in the marketplace and shifting the focus of regulatory debates. Growing demand for ride-hailing services underscores the relevance of investigating their impact on environmental sustainability and social inclusion. A key determinant of these impacts depends on their interactions with traditional modes of transportation. Such a relationship, however, has been explored mostly from a perspective of competition in contemporary research.

This paper seeks to shed light on the above concerns in Latin American cities by unpacking the links between ride-hailing and travel demand and is structured as follows. First, we begin by (i) gathering evidence on the characteristics of ride-hailing users, then we (ii) conduct a detailed examination of their travel patterns, and (iii) analyze how pricing and availability of public transit and alternative modes of transport affect mode choices to evaluate the potential of

[1] Ride-hailing services are defined as the provision of transportation services by a driver to a rider requesting a ride through a network facilitated and controlled by a third-party platform.

introducing an integrated scheme of ride-hailing and mass transit, where the scenario of the integrated scheme places ride-hailing as a filler of the first- and last-mile gap left by mass transit. The paper contributes to a growing body of literature focusing on cases outside of the Global North (Acheampong et al., 2020; Moody et al., 2021; Sabogal-Cardona et al., 2021; Vanderschuren and Baufeldt, 2018). A specific novelty of our research is the use of hypothetical scenarios where ride-hailing is combined with mass transit. The paper holds direct relevance for policy as it tests the feasibility of a hypothetical scheme integrating ride-hailing services and mass transit in large Latin American cities. Such research has the potential to reduce the cost of delivering public transit in peripheral low-density areas where it has been challenging to provide robust transit coverage, while increasing convenience, reliability, and comfort for public transit users compared to the current scenario. To the best of our knowledge, there are no studies to-date on the potential for ride-hailing integration with public transport in the Latin-American context from behavioral standpoint.

2. LITERATURE REVIEW

A large body research has examined the environmental and social impacts of ride-hailing services and other app-based mobility alternatives (Scholl et al., 2022). In particular, social researchers, policymakers and practitioners have focused on understanding the consequences and potential use cases of TNC-provided services in large metropolitan areas around the world (Chalermpong et al., 2022; Moody et al., 2021). Most research to-date on ride-hailing adoption demonstrates that the service tends to be used by urban, highly educated, and young people with high levels of income and tech savviness. Ride-hailing is also primarily used for non-work trips, including leisure, health, or household care related trips (Alemi et al., 2018; Dias et al., 2017; Sabogal-Cardona et al., 2021; Tirachini, 2020).

Other work has sought to understand how the built environment influences ride-hailing use (Malik et al., 2021; Sabouri et al., 2020) or how ride-hailing could increase or decrease total vehicle miles travelled VMT (Tirachini, 2020; Tirachini and Gomez-Lobo, 2019) in highly congested urban areas. A recent review highlights that even though ride-hailing is associated with people avoiding car ownership, there is an overall increase in emissions and VMT in cities with high levels of ride-hailing usage (McKane and Hess, 2023).

A key strand of research explores how the rising demand for ride-hailing as a mode of transport has impacted public transit ridership (Chalermpong et al., 2022; Zgheib et al., 2020) with several contrasting hypotheses cited regarding the mechanism through which ride-hailing could impact public transit. On the one hand, several scholars have argued that ride-hailing has the potential to decrease public transit ridership. Commuters who can afford it may choose to replace their public transit trips with ride-hailing. On the other hand, those who see ride-hailing as a reliable alternative to owning a car may choose to use public transit or micromobility for their regular trips and reserve ride-hailing for situations where public transit is not an option and/or use it to access a transit station (Sabogal-Cardona et al., 2021).

Literature examining whether ride-hailing services function as a complement or a substitute of public transport services (Hall et al., 2018; Lavieri and Bhat, 2019; Scholl et al., 2021a; Young et al., 2020) has found contradictory effects. Furthermore, in several markets, ride-hailing trips have been found to be door-to-door trips that would otherwise be completed via public transit or walking. Other strands of research suggests that ride-hailing can both compete with and complement public transit depending on specific contextual variables such as the condition and coverage of public transit, the scale of the city, proximity to commercial or employment hotspots, and levels of car dependance. One study in the U.S. found no substitution or complementarity effects of ride-hailing on services provided by public transit agencies in the United States

(Malalgoda and Lim, 2019). However, another study also in the United States found that Uber may be reducing public transport ridership in small cities but increasing it in large cities, as people may be using it as a feeder to bus and metro systems (Hall et al., 2018). Other variables that literature has found relevant in the competition-complementarity dilemma are the built environment, type of public transit, weather, and service delays (McKane and Hess, 2023).

A study in Ghana found that ride-hailing mainly competes with taxis but also with transit, concluding that 36% of ride-hailing trips would have been made in public transportation if ride-hailing were not available (Acheampong et al., 2020). In Bogota, a study suggests that 31% of current public transport trips could potentially become ride-hailing trips (Oviedo et al., 2020) given that they would be affordable by transit users. A study in Toronto (Young et al., 2020) showed that 31% of ride-hailing trips are competing with public transport, as they have similar travel times, but that 27% of ride-hailing trips could take more than 30 minutes if conducted in public transportation. Another study in Toronto, however, concluded that ride-hailing does not compete with public transportation (Habib, 2019), and transit users would prefer to keep completing their trips in public transit instead of switching to ride-hailing. Taking an affordability perspective in terms of at what extent individuals are likely to pay for ride-hailing, a study in Chengdu (the capital of the Sichuan Province in China) shows, as in the work in Young et al., (2020), that complementarity and competition are possible (Qiao and Gar-On Yeh, 2023). This study shows that around 38% of ride-hailing trips could be made in public transit; nevertheless, the number of potential transferable trips increases to 80% when commuting trips are included in the analysis. Qiao and Gar-On Yeh (2023) also highlight that ride-hailing is providing low-income populations without access to a car with a mechanism to engage in entertainment activities.

Research in Pittsburgh observed ten locations for six months and found that four of the locations were having less bus boardings at night during periods of increased ride-hailing usage (Grahn et al., 2021). Moreover, research from Pittsburgh concludes that substitution effect can vary across the city, with some locations suggesting a shift from public transit to ride-hailing and others not showing a shift. Authors argue that a location can show different trend depending on the time of the day considered. A plausible explanation for this variability is the surge price (Grahn et al., 2021), that makes ride-hailing fare more expensive at moments of increased demand (making public transit more attractive) and more affordable at moments of low trips request (making ride-hailing more attractive).

Other studies have looked at the possibility of integrating ride-hailing with transit. One of the earliest studies explicitly analyzing a potential integration of ride-hailing to mass public transit as a feeder was conducted in Beirut (Lebanon) and estimates a 2% increase in transit ridership (Zgheib et al., 2020). The study also shows that a reduction of 50% in the ride-hailing fare could increase transit modal share from 33.53% to 36.89%. The study also reveals that the integrated system of ride-hailing and mass public transit would be more popular among young people. Finally, others argue that under the right pricing and regulatory frameworks, ride-hailing services could potentially provide needed services and improve accessibility transit desserts and that ride-hailing improve accessibility in low-income neighborhoods with low to little public transit coverage and access to cars (Brown, 2019; Brown et al., 2022; Young et al., 2020).

3. Methods

To explore the potential effects of ride-hailing on public transit ridership we designed and conducted a stated preference survey was conducted in the cities of Bogota and Medellin (Colombia), and Mexico City (Mexico). The survey first asked respondents about their socioeconomic characteristics and their most frequent trip during a typical week. Then, respondents were presented with different scenarios through a discrete choice experiment, using their reported trip as a reference. They were asked to choose among a set of travel alternatives, with varying characteristics such as price, travel time, and mode, to conduct their usual or primary trip. The alternatives included options for making the trip using ride-hailing and options for making the trip in an integrated scheme of ride-hailing and mass transit. The methodology was based on two related analyses. First, a discrete choice model was fit to uncover individuals' preferences. Second, a simplified simulation was developed to test how much people would change their main mode of transportation under three hypothetical scenarios.

3.1 Study Area

Latin America is a large and diverse region with many growing and complex metropolitan areas. In this context, the selection of the case study cities was based on factors such as data availability, ease of survey application, and the characteristics of their urban transport systems. In all cities there is a solid supply of ride-hailing services. The urban areas of analysis included Bogota (including the town of Soacha), the Medellin Metropolitan Area, and the Mexico City Metropolitan Area. These cities are among the most populous metropolitan areas in the region, with Bogota estimated to have a population of around 11 million, Medellin around 4.1 million, and Mexico City 21 million. Appendix C includes a description of the main characteristics of each city.

Each city has a unique urban form and adoption pattern of public transport services. In Bogota, the Bus Rapid Transit (BRT) system, Transmilenio, is the backbone of the city's mobility. Transmilenio started operations in 2000 and for many years was considered the gold standard of efficient and high-quality public transit, serving as a model for urban transformation replicated in other cities in Latin America, Africa, and Asia (Gilbert, 2008; Hidalgo et al., 2013). However, Transmilenio now suffers from challenges related to overcrowding (Gilbert, 2015), service quality, coverage, fare evasion, crime, and sexual harassment (the latter of which disproportionately affects women). Bogota has also invested heavily in infrastructure for non-motorized transport including investments in bikeway infrastructure, the introduction of a bike-share system, the promotion of cycling (Oviedo and Sabogal-Cardona, 2022; Torres et al., 2013), and more recently has built a cable car system.

The city of Medellin also boasts several integrated public transport systems (Bocarejo et al., 2014). The backbone of mobility in Medellin includes a metro system connected to several cable lines that reach low-income neighborhoods in the mountains (Brand and Dávila, 2011; Levy and Dávila, 2017). The cable system was launched in 2004 and was considered an innovation that revolutionized urban policies. Like Transmilenio, the cable system soon became a gold standard and a model for other cities in Colombia and Latin America. Medellin also has Encicla, a completely free bike-share system (Builes-Jaramillo and Lotero, 2022). Despite these efforts, Bogota's and Medellin's transport system still face considerable challenges and are considered some of the most congested in the world (Garcia Ferrari et al., 2018).

Mexico City urban mobility system includes an extensive BRT and a metro system (Guerra, 2015), but jitneys (also known as micros or combis) still serve a lion's share of trips in the city. Jitneys are a semi-informal transport option known for their low quality, discomfort, and lack of regulation (Asimeng and Heinrichs, 2021; Flores-Dewey, 2019). Despite needing permission from authorities to operate, they still lack government regulation, financing, and management needed to provide adequate service (Dunckel Graglia, 2016; Sabogal-Cardona et al., 2021; Tirachini et al., 2020).

We argue throughout this study, that while ride-hailing services provide many benefits, there is the need for regulation of ride-hailing services to harness benefits in terms of accessibility and mobility while reducing their potential negative externalities such as increased congestion, emissions, and vehicle-miles traveled (Oviedo et al., 2021a; Puche, 2019). These services are authorized to operate in Mexico City. In Colombian cities, however, regulation and operation of TNCs remains undefined, with constant conflicts among owners and operators of conventional taxis, users, and regulators (Oviedo et al., 2021a, 2021b; Scholl et al., 2022). For example, in December 2019, Uber was banned from the country for not following regulations. A month later, Uber returned with essentially the same service, arguing that they were not selling trips but renting a vehicle with a driver for a short period of time, which is allowed under Colombian regulation.

3.2 Survey Design

Data were collected between September 13 and October 14 of 2020 using an online panel service[2]. Sample size and characteristics were calculated using the national census information and household travel surveys of each city and, in the specific case of Mexico, the intercensal survey. The sampling process was constrained by pandemic lockdown at that time. Although the panel is not a fully probabilistic method, it resembles a probabilistic sample. The survey was designed following a three-part structure, beginning with a section asking respondents about how they travelled before the pandemic and a description of the most frequent trip (Origin, destination, modes used, times, costs, etc.). This was followed by the stated preference exercise derived from the referenced frequent trip and ending with sociodemographic information and a free format commentary.

The stated preferences exercise was based on nine hypothetical scenarios based on the reference trip described (purpose of travel, origin and destination of the trip, arrival time restriction, who they were travelling with, if they had packages, etc.). The scenarios were shown to all respondents, regardless of whether they were active users of ride-hailing services and or had a smartphone to request a ride-hailing service. The individual could choose between three alternatives of travel modes: i) the mode of the most frequent trip, ii) an integrated scheme of ride-hailing plus mass transit, or iii) a ride-hailing service alone. Each alternative was described in terms of walk, wait and onboard time, and the out-of-pocket cost for the entire trip. In the preference exercise, the following alternatives were considered: car, motorcycle (only in Bogota and Medellin), mass transit, TNC, taxi and ride-hailing plus mass transit. In appendices A and B, we provide more information about the discrete choice experiment.

An example of the choices is shown in Figure 1 (information is presented in English, but the language spoken in the three zones of study and how the survey was programmed was in Spanish).

[2] Panel services are used in market research and consist of a large group of people who decide to participate in studies due to a financial motivation. The panel service bridge researchers and potential participants of studies. A private panel service was responsible for inviting participants, managing data collection, distributing the survey link, and incentivizing individuals to complete the questionnaire. Quotas were defined by sex, age, and socio-economic strata of the household.

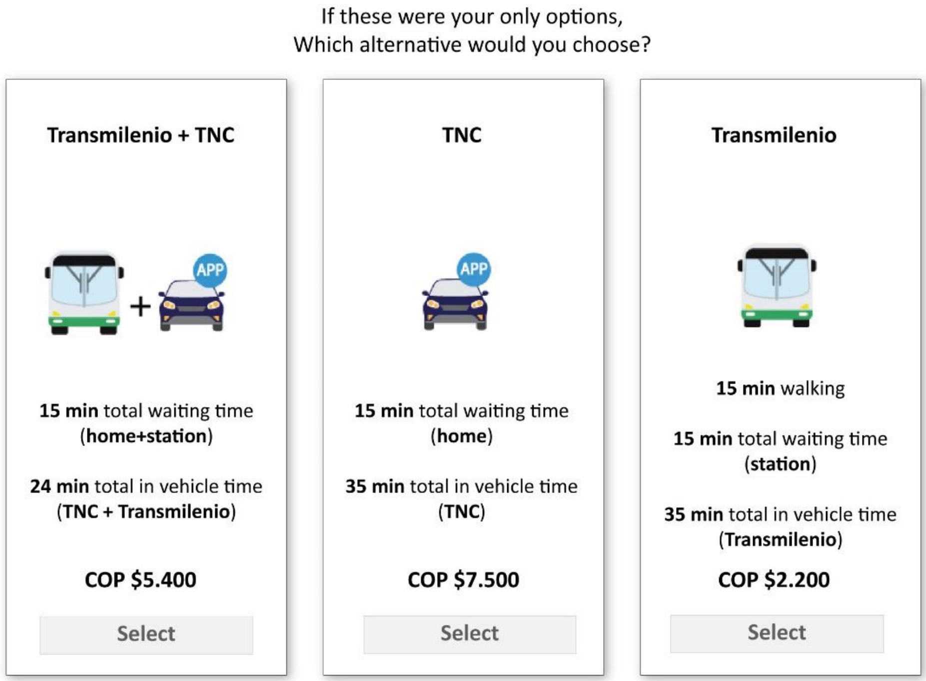

Figure 1. Example of the stated preferences exercise (Bogota) for illustrative purpose only

We chose to present the travel segments (walk, wait and vehicle time) separately because of the possible differences in their respective valuations.[3] A pivot design is used for the travel time (i.e., the time and cost options to be shown on each card were related to their initial responses), so that the times and costs shown would be familiar to the respondent and within the range of values of everyday travel before the Coronavirus pandemic (Rose et al., 2008). Thus, the travel time calculation for each of the alternatives was based on the value reported by the respondents and the operational speed of each mode of transportation. We used a Bayesian efficient experimental design, which maximizes the likelihood of obtaining significant parameters (Type II error), starting from a set of preliminary values, and considering a certain choice behavior for the definition of viable options to be presented (Rose and Bliemer, 2013).[4] Participants were asked to respond a total of nine mode choice cards.

The design aimed to present respondent's meaningful differences between the levels of the attributes to avoid biases of indifference between alternatives or extreme probabilities. The survey design was carried out in the software program Ngene 1.1.2. For the travel time and cost coefficients of the utility function, a priori values were extracted from recently calibrated citywide models for Bogota, Valle de Aburrá Mobility Master Plan, and an available mode choice model for Mexico City.

[3] Several studies have found that walking and waiting time generally have a higher value than on-board time in the vehicle (Wardman et all, 2016).

[4] The aim of this method is to achieve an efficient survey design, that is, one that provides enough number of hypothesis and significance of the alternatives being included in such a way that minimizes the respondent's burden while allowing for the estimation of significant parameters. This involves a complex combinatorial problem between the different levels of attributes of each alternative, thus optimization methods are applied to find a suitable design using specialized methods and software.

Appendix A and B contains the information on the alternatives presented by type of user and the ranges of the attributes considered in the stated preference exercises.

3.3 Sample

The survey responses yielded a sample of 1,551 individuals for Bogota, 1,581 for Medellin and 1,570 for Mexico City. Across the three cities, we observe a similar distribution of responses by gender, as 50% (Bogota) and 52% (Medellin and Mexico City) of the respondents self-described as female. With respect to the age of the respondents, we observe that the highest proportion of the sample was between the age of 30 and 60 years old, representing 58% of the sample for Bogota, 52% for Medellin and 59% for Mexico City. People over 60 years of age represent the lowest percentage of the overall sample (3% - 6%). This is relevant and could produce some problems in the results for this age group, as the survey required internet connection and literacy, and people in this age group are the ones who use this service the least. Appendix C shows the socioeconomic distribution of the sample collected and of the population in each city.

We use socioeconomic strata (SES) as proxy to income. In Colombian cities, SES are divided in six categories highly correlated with household income, although not defined by it. For the analysis, we grouped them into three categories: low (strata 1 and 2), medium (strata 3 and 4) and high (Strata 5 and 6). In the case of Bogota, the highest number of collected surveys (52%) was grouped in the low SES strata, followed by the medium strata (34%) and finally the high strata (14%). In the case of Medellin, the medium strata concentrated the higher number of surveys (50%), followed by the low strata (40%) and finally the one in the high level (10%). For Mexico City, a different methodology was used to define SES. Like Bogota and Medellin, the strata are not defined directly by income, but highly correlated to it. The category of medium socioeconomic strata (C/C-) had the highest number of surveys (38%), followed by the high strata (33% surveys of A/B/C+) and finally the low strata (29% of D+/D/E).

Of special interest for the research is the main transport mode for the respondent's most frequent trip. In all cases, more than half of the reported trips in all cities were via mass transit, making it relevant for the research question, with 55% in the case of Bogota and 60% for Medellin and CDMX. A higher response rate for women using mass transit was found, that is also the case for taxi and TNCs. Men reported a higher proportion of use of private vehicles. Appendix D shows the distribution of the main mode of transport used by people in the survey sample and the population in each city; the results are similar, but it is difficult to compare the percentage of trips made by TNC users as the mobility surveys did not specifically ask about these trips.

As per the information provided and based on the most frequent trip reported before the pandemic, commuters in the lower SES groups had a higher probability of using the mass transit alternative and a lower probability of using a car. Their willingness to pay for quicker services or lower waiting times has an important influence over their travel mode choice. Typically, people in high SES households have a higher preference for the alternatives of car, taxi, and TNC. In the Colombian cities the use of motorcycles particularly for men in the lower SES is especially important.

When inquiring about the main trip purpose of the most frequent trip, "work" was the purpose most often stated. For the case of Bogota, 49% of the female respondents selected work as their main purpose for travelling, 65% for male respondents. In the cases of the areas of study in Medellin and Mexico City, the distribution is similar to the one in Bogota. "Work" is the main purpose of the most frequent trip, followed by "Study". For the case of Bogota, approximately 52% of the most frequent trips are made without a companion, 24% of the trips are made with one companion and the remaining 24% are made with more than one companion. These characteristics are very similar to the study areas of Medellin and Mexico City. Regarding membership to a mobile data plan, most of the survey respondents in the three areas of study stated that they were paying for a plan: corresponding to 69% of the sample for Bogota, 65% for Mexico City and 58% for Medellin.

3.4 Description of the model structure

We employ a discrete choice modelling approach to estimate utility functions to analyze how pricing and availably of public transit and alternative modes of transport affect mode choices between ride-hailing, public transit and public transit combined with ride-hailing. The basic structure used to derive the utility function for each alternative and person is as follows:

$$V_{in} = ASC_{in} + \beta_{twalk} * Twalk_{in} + \beta_{twait} * Twait_{in} + \beta_{ivtt} * Tivt_{in} + \beta_{cost} * Cost_{in} + \sum \beta_{SC} * SCH_n$$

Where the subindex "i" refers to each of the alternatives of the experiment, and the subindex "n" refers to the person making the decision; a more general subindex indicating the availability of alternative is omitted for ease of description in this paper. The variables are to be understood as follows:

- ASC_i corresponds to alternative specific constants.
- $Twalk_{in}$, $Twait_{in}$ and $Tivt_{in}$ indicate the walking, waiting and in vehicle travel time of each trip, respectively, all measured in minutes for alternative i and individual n
- $Cost_{in}$ refers to the total out-of-pocket cost of the trip for alternative i for person n measured in the local currency.
- SCH_n refers to the socio-economic characteristics of the individuals, some of these are expressed as additive to the alternative specific constants.

The corresponding coefficients are estimated for each model structure. The modelling process began with a Multinomial MNL model specification without any socioeconomic characteristics considered. After, models including these variables were run to capture the heterogeneity of taste and allow for interaction with individual characteristics for future simulation. The systemic variation of tastes that were found to be significant corresponded to the interactions between the alternatives of the stated preferences exercise, the socioeconomic characteristics of the individual and the trip.

To estimate systemic variation of preferences, we included variables such as gender (whether the person if male or female), car ownership, and if the person has a cellular data plan (access to internet without a Wi-Fi connection) for his or her smartphone. Given that it is difficult to obtain consistent and reliable estimates for household or personal income, we relied on the socioeconomic stratum (SES) used by government (Colombia) or marketing agencies (Mexico) as a proxy variable. This classification is relevant, as it is typical that travelers in population groups correlated to higher incomes tend to have higher willingness to pay for travel time reductions and different attitudes towards certain models. It is also the case that in Latin-American cities urban space is highly segregated, affecting the values of the level-of-service variables such as times and costs. In many cases, the periphery is home to lower income groups exposed to longer travel and wait times and more arduous conditions for walking. Low-income groups have less disposable income to use in transportation, therefore have access to lower quality modes of transport and have to spend more time in their daily commutes (Scholl et al., 2022). Additionally, these groups also tend to make more transfers to complete the usual trip to work or school. The literature also shows that women are more affected by these patterns than men, as the family income is not distributed uniformly and decisions over the use of the household vehicle (auto or motorcycle) is affected by traditional family structures.

Apart from the initial MNL structure, Nested Logit NL and Mixed Logit ML structures were also tested. These hierarchical models were estimated to account for possible correlation in the error terms between the alternatives of ride-hailing and ride-hailing plus mass transit. The lambda nest is an indicator of the correlation between the alternatives, closer to 1 means a lower correlation and higher independence. It is interesting to note that in all cases but Mexico City, the null hypothesis that the coefficient for the nest was equal to 1 was rejected. This coincides with the fact that the likelihood ratio test for comparing model structures also rejected the hypothesis of difference between MNL and NL for Mexico City. Notwithstanding this result, the NL structure was used to analyze the results in the three cases. Although it is not clear why this difference arose from the data, we believe that the high gap in the cost of the ride-hailing alternatives compared to ride-hailing plus public transport in Mexico could lead people to not observe a correlation between these alternatives, in part because travel times and cost per minute for ride-hailing are higher in the CDMX than in Colombian cities. It could also be due to the fact the TNC facilitated services operate legally in Mexico City and not in Colombian cities.

It is important to note that one of the drawbacks of data coming from stated preferences surveys is that the repeated observations for the same individual contain correlations, known as panel effect. To control this effect, it is advisable to estimate models with more advanced and flexible models like mixed logit models; these were estimated for the three study areas. For these, 1,000 draws were generated for each of the alternatives. The results show that the panel effect is highly significant and generates a higher likelihood value when compared with the hierarchical models (NL). Recent work (Zgheib et al., 2020) provides an alternative model structure particularly suited to study the combined offer of ride-hailing plus mass transit, providing a more general model for the first/last-mile integration to mass transit. Our survey did not allow for such specification but remains an interesting approach to be explored further in the region. Estimation of model parameters was done with the Apollo software (Hess and Palma, 2019). For the simulations, sensitivity scenarios were formulated to reflect various transport policy and pricing policy scenarios to shed light on how modal preferences could change depending on socioeconomic characteristic of users and attributes of the transport alternative.

4. Findings

4.1 Discrete choice model

Tables 1 to 3 show the results of the NL models (for Bogota, Medellin, and Mexico City) where the utility function of the alternative integrated scheme of ride-hailing plus mass transit is compared to the existing options. Although a direct comparison across the three cities is not straightforward, in this section we present a summary of common findings. Unique results for each city are also introduced. For the trips used to evaluate the options vis-à-vis the combined ride-hailing plus mass transit, the auto and motorcycle were not universally preferred as the corresponding Alternative Specific Constants ASC were not found to be neither higher than transit and non-statistically significant. Notwithstanding, these results are maintained in all functions for consistency with basic assumptions of the model specification.

It is important to note that in the utility functions there are specific variables by mode of transportation (for example, Walking time in transit, Cellular data plan in TNC users, among others). Different segmentations of systematic variations of tastes related to household socioeconomic stratum, gender, availability of more than one vehicle in the household and possession of cellular plans were tested. However, some parameters did not present statistically significant differences for these variations, for example, the parameter of cost of transit is similar regardless of the socioeconomic strata of the household.

Table 1. Estimates of the Nested Logit NL model - Bogota

	Transit	Transit + TNC	TNC	Taxi	Auto	Motorcycle
ASC	---	-0.986***	-1.187***	-1.278***	0.011	1.191***
Female	-0.16*	---	0.421***	---	---	---
Travel cost (Thousand Colombian pesos)						
Low (Strata 1 and 2)			-0.129***			
Medium low (Strata 3)	-0.385***	-0.211***	-0.108**		-0.144***	-0.331***
Medium high (Strata 4)			-0.094**			
High (Strata 5 and 6)			-0.074***		-0.077***	
Cellular data plan	---	0.499***		---	---	---
More than 1 car in the household	---	---	---	---	0.569**	---
Walking time (minutes)						
Low - Medium (Strata 1, 2, 3 and 4)	-0.012***		---	---	---	---
High (Strata 5 and 6)	-0.032		---	---	---	---
Waiting time (minutes)						
Low - Medium (Strata 1, 2, 3 and 4)		-0.012***			---	---
High (Strata 5 and 6)		-0.029**			---	---
In vehicle travel time (minutes)			-0.014***			
Lambda Nest - Transit and TNC-Transit	1^{FIXED}	0.736***			1^{FIXED}	
Number of observations			10,233			
Number of people			1,137			
Estimated parameters			27			
Log-likelihood (initial)			-8650.62			
Log-likelihood (final)			-7593.44			
Adjusted Rho-squared			0.1486			

Note: Significance levels are indicated as follows: *p<0.1, **p<0.05, ***p<0.01

Table 2. Estimates of the Nested Logit NL – Medellin

	Transit	Transit + TNC	TNC	Taxi	Auto	Motorcycle
ASC	---	-1.450***	-2.02***	-3.227***	-0.618	-0.294
Female	-0.239**	---		0.764*	---	-0.383*
Travel cost (Thousand Colombian pesos)						
Low (Strata 1 and 2)			-0.090***		-0.245***	
Medium (Strata 3 and 4)	-0.524***	-0.237***			-0.186**	-0.247***
High (Strata 5 and 6)			-0.068**		-0.153***	
Cellular data plan	---	0.245***		---	---	---
More than 1 car in the household	---	---	---	---	0.379	---
Walking time (minutes)						
Low (Strata 1 and 2)	-0.024***		---	---	---	---
Medium (Strata 3 and 4)	-0.043**		---	---	---	---
High (Strata 5 and 6)	-0.054*		---	---	---	---
Waiting time (minutes)						
Low - Medium (Strata 1, 2, 3 and 4)		-0.014***			---	---
High (Strata 5 and 6)		-0.038***			---	---
In vehicle travel time (minutes)						
Low - Medium (Strata 1, 2, 3 and 4)			-0.015***			
High (Strata 5 and 6)			-0.036***			
Lambda Nest - Transit and TNC-Transit	1^{FIXED}	0.510***			1^{FIXED}	
Number of observations			14,229			
Number of people			1,581			
Estimated parameters			29			
Log-likelihood (initial)			-13,206			
Log-likelihood (final)			-11,005			
Adjusted Rho-squared			0.1676			

Note: Significance levels are indicated as follows: *p<0.1, **p<0.05, ***p<0.01

Table 3. Estimates of the Nested Logit NL model - Mexico City

	Transit	Transit + TNC	TNC	Taxi	Auto
ASC	---	-0.165	-1.141***	-1.622***	-0.96***
Female	---	---	0.325***	---	0.466***
Travel cost (Mexican Pesos)					
Low (E, D or D+)	-0.05713***	-0.03917***		-0.011***	
Lower middle (C- or C)				-0.0092	
Upper middle (C+)				-0.0080*	
High (B or A)				-0.006***	
Cellular data plan	---	0.217***		---	---
More than 1 car in the household	---	---	---	---	0.297***
Walking time (minutes)	-0.022***		---	---	---
Waiting time (minutes)	-0.031***				---
In vehicle travel time (minutes)	-0.010***				
Lambda Nest - Transit and TNC-Transit	---	0.900***		---	---
Number of observations	14,112				
Number of people	1,568				
Estimated parameters	20				
Log-likelihood (initial)	-19,568				
Log-likelihood (final)	-11,723				
Adjusted Rho-squared	0.0762				

Note: Significance levels are indicated as follows: *p<0.1, **p<0.05, ***p<0.01

In Bogota and Mexico City, women are more likely than men to prefer ride-hailing services. Based on the results found, women in Bogotá are willing to pay more for a TNC ride, between $ 0.8 and $ 1.4 USD extra (ceteris paribus) compared to men, and up to $3.2 USD in the case of CDMX. The influence of safety and comfort in these transport modes can be playing an important role for women (Sabogal-Cardona et al., 2021; Scholl et al., 2021b). In Medellin, the same was found for taxi services.

In relation to the socioeconomic strata SES of the household of the individual, there are significant differences in the choice of the main mode in the different groups. People who live in low-income SES have a higher probability to choose mass transit alternatives and a lower probability of using cars. Conversely, people who live in high-income SES have a higher preference for the alternatives of car and ride-hailing. This tendency is exacerbated in homes where more than one car is owned. The willingness to pay for a one-minute travel time saving is 80% higher in high socio-economic strata than in low socio-economic strata in Bogota and CDMX, and up to 300% higher in Medellin.

Additionally, for all three cities, the results show that people with cellphone data plans have a greater tendency to use both ride-hailing and the ride-hailing plus mass transit alternative. This is coherent considering that internet access is required for its use and Wi-Fi alternatives may not be freely available in all trip origins.

In-vehicle travel time values by car in Medellin and Bogotá are under 3.00 USD/hr, Mexico City values are between 2.50 USD/hr and 5.00 USD/hr. These values are low compared to developed countries, for example, in the UK, values of 7.78 (USD/HR) have been found (Wardman et all, 2016). This implies that people in developing countries are less willing to pay for travel time savings given their budgetary constraints or the opportunity costs associated with travelling.

On-board time values by mass transit are similar in the three study areas (0,50 – 1,00 USD/hr) and lower than that of auto users. It is important to mention that the willingness to pay increases if mass transit is combined with TNC service (ride-hailing plus mass transit). This opens the possibility of further studying the combination of the right pricing with the increased level of service on walking and waiting as the structure whereby the combined alternative could be viable.

Regarding walking and waiting times, we obtained higher penalties attributed to those parts of the trip in Mexico City and Medellin than in the city of Bogota; many reasons could be linked to this, but the study in inconclusive in this regard. Improved walking infrastructure, topography, weather, distances, and other conditions may have an influence on this result. This is an important finding given the level of service conditions stated above. Cities with higher walking and waiting penalties may be linked to higher probability of use of the combined TNC plus transit option. We also found that income groups were more likely to penalize increased walking and waiting times, which combined with high willingness to pay for reduced in vehicle travel time could tip the balance of modal choice to the car as the primary mode of transportation for this group.

4.2 Pricing scenarios

Using the outputs from the previous results, we model behavioral changes in terms of the willingness of travelers to switch from their current primary mode to a combined scheme of ride-hailing plus transit. For this purpose, it was necessary to identify the service levels of each travel alternative, using Google API, which provides estimates of the times and distances traveled by each mode of transport in the different stages of the trip.

For the ride-hailing plus mass transit alternative, we assumed that the time the person walked (accessing and egressing the station) to mass transit would be done in TNC, therefore, the walking time is assumed to be zero. To calculate the ride-hailing travel time, we considered the speeds and distances by walking and driving obtained from the Google API. Furthermore, travel cost estimates for each alternative were calculated considering the values reported by people in the surveys collected, the current fares of ride-hailing, taxi, and mass transit in each study area.

As mentioned in the methods section, three hypothetical tariff reductions scenarios are analyzed: i) a scenario of reducing TNCs fare by approximately 25% of its current cost (this would affect both the ride-hailing service and the ride-hailing plus mass transit service), ii) a scenario of reducing the TNC fare only for the ride-hailing plus mass transit alternative by approximately 25%, and ii) a scenario of reducing the TNC fare only for the ride-hailing plus mass transit alternative by approximately 50%. Results are presented in Table 4.

Table 4. Change in market share for simulated scenarios

	BOGOTA			**MEDELLIN**			**Mexico City**		
Alternatives	**Difference from base (S - Base)**			**Difference from base (S - Base)**			**Difference from base (S - Base)**		
	S1	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**
Car	-1.14%	-0.24%	-0.53%	-0.88%	-0.30%	-0.68%	-2.04%	-1.10%	-2.54%
Motorcycle	-0.38%	-0.11%	-0.24%	-0.65%	-0.28%	-0.63%	NA	NA	NA
Taxi	-0.78%	-0.13%	-0.29%	-0.53%	-0.18%	-0.40%	-0.83%	-0.40%	-0.89%
TNC	3.51%	-0.49%	-1.01%	2.11%	-1.07%	-2.18%	3.22%	-0.96%	-2.09%
Mass transit	-1.81%	-0.76%	-1.53%	-1.20%	-0.68%	-1.47%	-4.26%	-2.66%	-5.82%
Mass transit + TNC	0.55%	1.67%	3.53%	1.15%	2.52%	5%	3.83%	5.05%	11.26%

S1: reducing TNCs fare by 25% of its current cost.
S2: reducing the TNC fare only for the ride-hailing plus mass transit (integrated scheme) alternative by 25%
S3: reducing the TNC fare only for the ride-hailing plus mass transit (integrated scheme) alternative by 50%

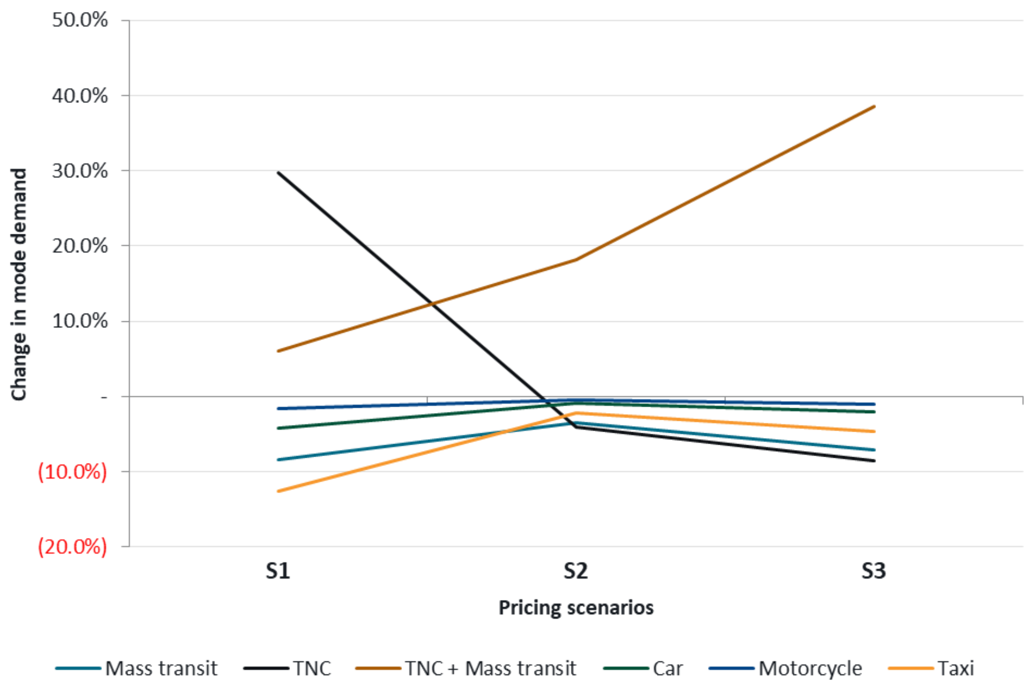

Figure 2. Change in mode demand for simulated scenarios in Bogota.

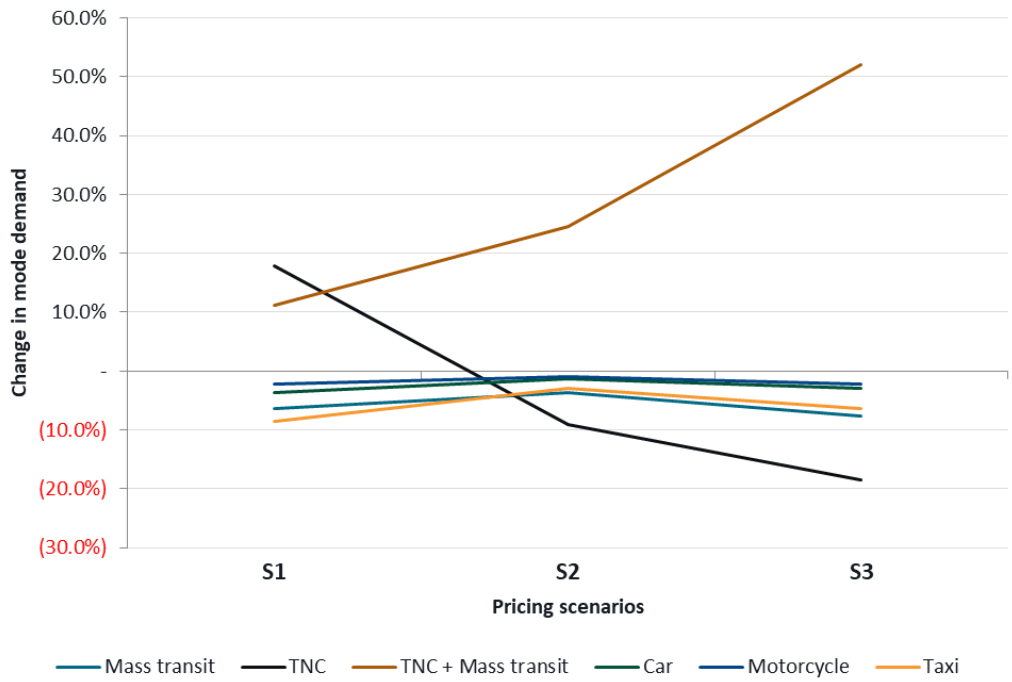

Figure 3. Change in mode demand for simulated scenarios in Medellin.

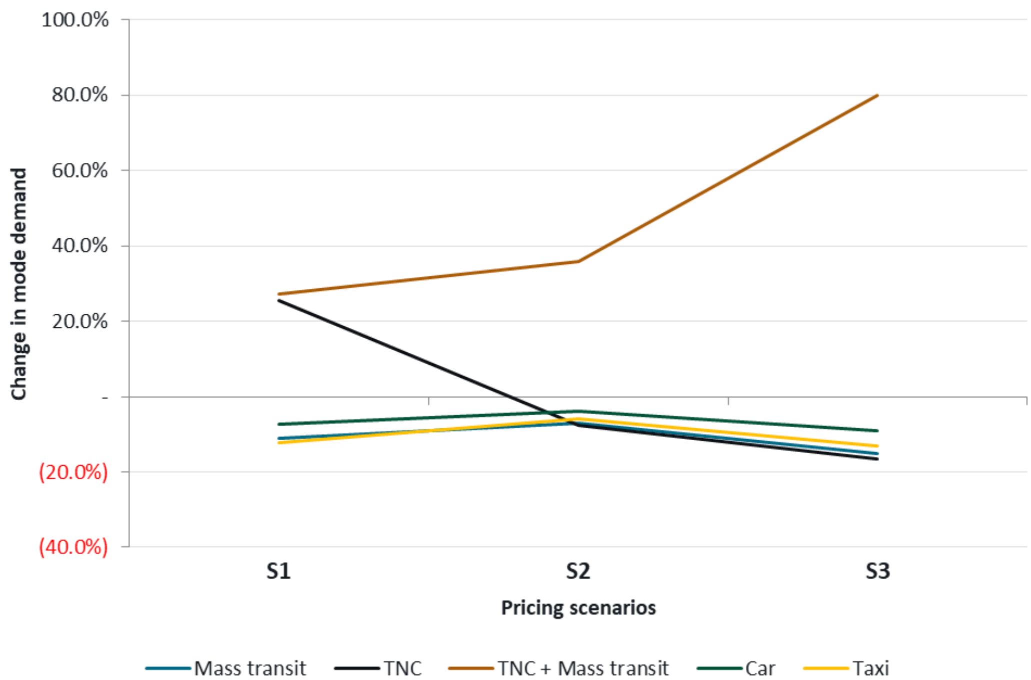

Figure 4. Change in mode demand for simulated scenarios in Mexico City

5. Discussion

In the only scenario (scenario 1) reducing the fare of ride-hailing (by 25%) for ride-hailing trips and trips completed in the integrated scheme (ride-hailing plus mass transit), ride-hailing increase its demand in the three cities (3.5% in Bogota, 2.1% in Medellin, and 3.2% in Mexico City). These new ride-hailing trips would come mainly from mass transit (losses in mass transit systems would be 1.8% in Bogota, 1.2% in Medellin, and 4.3% in Mexico City) without much new ridership coming from other modes (for example, reductions in car ridership would be 1.14% in Bogota, 0.88% in Medellin, and 2.04% in Mexico City). More importantly, the integrated scheme does not reach ridership levels that replace the potential losses in mass transit ridership (expected demand would be 0.55% in Bogota, 1.15% in Medellin, and 3.83% in Mexico City) and, for the cases of Bogota and Medellin, these values are small when compared to the potential gains in ride-hailing passengers. In other words, jointly reducing the fare of TNCs in ride-hailing and in a combination of ride-hailing plus mass transit could negatively impact mass transit (losses in ridership) without much compensation from mass transit users moving to the integrated scheme or from people moving away from cars and motorbikes. An interesting result is that Bogotá, one of the cities analyzed, would show the lowest increase in the ride hailing plus mass transit demand, which may be related to the fact that this city has a higher rate of accessibility to mass transit and a greater geospatial distribution of public transport stations, which results in shorter access and egress times to the system.

This result provides insight into how to regulate pricing if moving towards an integrated system. It must be a clear differentiation between door-to-door ride-hailing trips and ride-hailing trips that are done as a first- or last-mile connection to mass public transit. The former should not have any kind of subsidy or fare discount, while subsidies and discounts for the latter make sense if the policy goal is to increase transit ridership. Nevertheless, and as we start to discuss in the next paragraph, an integrated scheme of ride-hailing and mass transit does not seem feasible because even with considerable reductions in the fare, the integrated system would only attract a small proportion of additional trips.

As expected, in the other two hypothetical pricing scenarios reducing the fare only in the integrated scheme (ride-hailing plus mass transit), the integrated scheme gathers ridership from the other modes, including mass transit. For example, the integrated scheme in Bogota could result in a potential modal share of 1.67% in the second scenario and 3.53% in the third scenario. Nevertheless, in Bogota and Mexico City most of the ridership would come from current users of mass transit systems, who are more likely to change their mode (towards the integrated scheme) than current users of other transport alternatives. More precisely, if a 25% discount in the fare is introduced to the ride-hailing trips that are part of an integrated system serving as first- or last-mile feeder alternatives, then mass transit ridership would increase by 0.91% in Bogotá, 1.84% in Medellin, and 2.39% in Mexico City.

We consider these numbers of additional passengers to be low given that a 25% discount on the ride-hailing fare is a very ambitious proposal. In the simulations presented in the previous section, models were forced to assume a reduction in the fare and produced the most likelihood output, but how to achieve such a discount in real-life remains a challenge and can probably be achieved only by using public funds. Moreover, a probable situation is that TNCs could end up receiving more public-funded money (via the subsidy of the 25% in the fare) than public transit (via the fare paid by the additional ridership). Therefore, if the goal is to improve public transit, then it would make more sense to transfer that money directly to fund public transit. The situation for the hypothetical integrated system does not improve when considering that data and results presented in this research do not consider additional costs in its implementation, something that may be complex in operational terms and merits future research. For example, additional questions that should be considered include, how the implementation could take place, infrastructure requirements for such integration (i.e. infrastructure for the pick-ups and drop-offs for first- or last-mile ride-hailing trips), specialized payment methods such as an additional mobile application, or any other technological innovations that need to be considered.

Despite the fact that the evidence presented in this paper speaks against the feasibility of integrating ride-hailing into mass transit systems, we believe that a complementarity interpretation of the results sheds light on how ride-hailing, and app-based mobility in general, can be mobilized to improve public transit. Coming back to the results introduced in the previous section and to Table 4, two important insights emerge. On the one hand, there is a small proportion of car users that are willing to give up car-based mobility in favor of mass transit if, somehow, they can combine mass transit with other alternatives (in this case by using ride-hailing). An hypothetical explanation is that this segment is not able to access to mass transit stations or that part of their trip in public transit is inconvenient or low-quality or due to a complete lack of public transit to complete the last or fist mile of their trips, they may otherwise have needed to walk long distances. On the other hand, results also imply that a small share of current mass public transit users are willing to pay a premium fare to combine their trips with TNCs. We do not know why this is happening, but a possible explanation is that this other segment is willing, and has the economic conditions, to pay more in order to get a better service assuming that the ride-hailing part of the trips would save travel times and improve comfort.

Regardless of the reasons why these two segments emerge, if for them the integrated scheme works, then policy should focus on finding specific solutions that if scaled up would improve access and environmental sustainability. The issue remains about how to ensure a significant fare reduction in the ride-hailing part of the trip without compromising public transit demand. A potential solution is the development of demand responsive shared mobility options, where several users can travel together in the same vehicle and collectively pay the fare. This could imply considerable fare reductions not only for the two groups that we are now considering, but in general to the overall population. Moreover, responsive shared mobility services could be a more sustainable transport alternative than regular ride-hailing or than car-based mobilities.

Such a shared mobility alternative, Microtransit, in fact, is gaining popularity in the Latin American and the Caribbean region. Click or tap here to enter text.Click or tap here to enter text.Operating with small buses or minivans, microtransit services can be requested and paid through a mobile application. Microtransit, emerged in Europe with experiments such as Kutsuplus in Finland (Haglund et al., 2019; Rissanen, 2016) and has since sparked several pilots across the world (Westervelt et al., 2018). A key impetus for microtransit is to fill gaps in transit deserts, where mass transit systems are not cost effective. As a consequence, these systems regularly operate in smaller vehicles, and without fixed routes and schedules. On the contrary, routes are demand responsive and adapt to what users need.

Before the pandemic, Mexico City witnessed the rise of two microtransit start-ups, Jetty and Urvban, that were gaining popularity (Flores-Dewey, 2019; Tirachini et al., 2020). One of the main arguments for the early success of Jetty was that, in the context of low-quality, unreliable, and unsafe and largely unregulated public transit, such as jitneys services in Mexico City, commuters viewed microtransit as a means to improve their mobility and access without paying a ride-hailing fare or without the cost of owning and sustaining private vehicles. Similarly, some car-users, tired of driving in congestion but not attracted to the same low-quality public transit, saw microtransit as a middle ground.

We highlight that the simulations in this paper were used to predict the choice of transport mode per individual based on the socioeconomic characteristics of the people surveyed and the trips made. Given the findings, it may be relevant for future research to consider the potential integration of microtransit and other collective forms of on-demand services, whose vehicles have a higher occupancy rate than those of the TNC service, with public transit. This could counteract some of the negative effects of policy implementation (increased vehicle congestion) and be attractive for areas with low accessibility to public transport where people with lower income levels would benefit the most.

Finally, the study has some limitations that could be addressed in future research. For example, trips other than the reference (typical, most frequent) trip could be included in the analysis. Moreover, it would be relevant to control for the ability of travelers to request a ride-hailing service. In this study we assume that people older than 60-year-old use a smartphone and interact with any ride-hailing mobile application, but this digital literacy might not hold for the entire population. Another limitation is that data was collected during the Coronavirus pandemic and results can, to some extent, be biased towards ride-hailing by concerns of COVID contagious in crowded spaces as is the case of public transit.

6. Conclusions

This article presents the results of the mode choice models calculated for Bogota, Medellin, and Mexico City based on stated preferences surveys. We find that women have a higher preference for ride-hailing services than men. On the other hand, high SES is associated with a higher preference for ride-hailing and a lower preference for taxi services. Moreover, there is more attachment to cars in these strata. With the aim of comparing changes in the travel mode choice in a hypothetical policy scenario, simulations of three modeling scenarios were developed, considering a new alternative of transport: ride-hailing service as a complement to mass transit. For this, we use the Google API to determine the service levels of each transportation alternative.

Scenario 1, under the considered assumptions, the alternatives to which people would shift vary depending on the area of study. For Bogota and Medellin, the TNC alternative would capture more demand, while for Mexico City, the TNC plus mass transit alternative would prevail. However, in this scenario, there is a decrease in demand for mass transit, an undesired effect that could increase current traffic congestion levels and greenhouse gas emissions. In future research, however, it would be interesting to evaluate whether it could improve mobility by increasing trip rates among poorer groups who would not otherwise be able to travel, given distance to transit and current prices.

Under the considered conditions and assumptions in Scenarios 2 and 3, an integrated scheme of ride-hailing and mass transit system incorporating reductions in the current cost of ride-hailing trips, could absorb demand from all other modes. Nevertheless, it is important to highlight that most of the people who would use the ride-hailing plus Mass Transit alternative would have otherwise used the Mass Transit alternative. Moreover, reductions in car trips would be relatively low in Bogota and Medellin (0.9% in Bogota and 1.30% in Medellin), when considering 25% reduction in the fare of ride-hailing. However, for Mexico City, the reduction is relatively high. (4% in Mexico City). The best possible scenario is one where demand is drawn from the private vehicle by combining the flexibility of on-demand ride-hailing and the speed of mass transit to rival the convenience of the private car. However, results suggest that under current conditions, this would not be car user's preferred choice.

Focusing on the second scenario, additional transit ridership after accounting for people changing from their current use of public transit to the proposed integrated system would be 0.9% for Bogota, 1.8% for Medellin, and 2.4% for Mexico City. These estimates are lower than expected and suggest that an integrated system of ride-hailing and mass transit is not feasible. Additional transit ridership would be low, and a 25% discount would be difficult to achieve for all trips.

Nevertheless, results also suggest that another alternative would be interesting for people: microtransit services. The small changes from car-based mobility towards the integrated scheme implies that there is a small proportion of people willing to pay a higher fare (compared to the current cost of public transit) to get a better public transit services and avoid using cars. This is also the case for a proportion of people travelling regularly in other transport modes (public transit included).

There is an implicit risk of incentivizing the increase in vehicle-miles and emissions of car-based on-demand services, which requires purposeful action from the public sector to mitigate the loss of transit riders. Such action requires active communication with the public and the development of partnerships with the private sector. The implementation of a system such as the one assessed in this paper should also incorporate considerations for technological transitions to cleaner vehicles for flexible services, interchange infrastructure to facilitate seamless connectivity, and the development of integrated pricing mechanisms in tandem with the ride-hailing operators.

Appendix A. Choice alternatives presented in the stated preference exercise by user type.

	Alternatives presented in declared preference exercises					
Mode of the most frequent trip	**Mass transit**	**Mass transit + TNC**	**TNC**	**Car**	**Motorcycle**	**Taxi**
TNC	✓	✓	✓			
Mass transit	✓	✓				
Car		✓	✓	✓		
Motorcycle		✓	✓		✓	
Taxi		✓	✓			✓

Appendix B. Range of attributes considered for each alternative in the stated preference exercise.

Alternative	Walking time	Waiting time	Boarding time	Cost
Mass transit	7 - 15 - 20 min	7 - 15 - 20 min	80% - 100% - 120% [1]	0.26 – 1.76 USD
Mass transit + TNC		10 – 15 - 20 min	70% - 90% -110% [1]	1.1 – 2 USD
TNC		5 - 10 - 15 min	80% - 100% - 120% [1]	50% - 75% - 100% [2]
Car			80% - 100% - 135% [1]	*Cost of operation*: 0.019 – 0.050 USD per minute *Parking cost*: 0.73 - 2.3 USD
Motorcycle			90% - 110% - 130% [1]	*Cost of operation*: 0.08 USD per minute *Parking cost:* 0.81 - 1.5 USD
Taxi		5 - 10 - 15 min	80% - 100% - 120% [1]	50% - 75% - 100% [2]

[1] Percentage of travel time reported by the person on the most frequent trip. These percentages vary by design and study area.
[2] Percentage of TNC cost for each city. These percentages vary by design and study area.

Appendix C. Socioeconomic distribution of the sample collected and of the population in each city.

	Sample collected			Population		
	Bogota	**Medellin**	**CDMX**	**Bogota**	**Medellin**	**CDMX**
Population by sex						
Male	49%	47%	48%	52%	48%	48%
Female	51%	53%	52%	48%	52%	52%
Population by age						
15 -29 years of age	38%	46%	36%	33%	43%	30%
30-44 years of age	33%	35%	40%	28%	22%	29%
45-60 years of age	24%	17%	19%	22%	19%	25%
Over 60 years of age	5%	3%	5%	16%	15%	16%
Population by household socioeconomic strata						

	Sample collected			Population		
	Bogota	Medellin	CDMX	Bogota	Medellin	CDMX
Low	50%	36%	34%	49%	51%	51%
Medium	41%	52%	37%	46%	39%	35%
High	9%	12%	29%	5%	10%	14%

Appendix D. Distribution of the main mode of transport used by the people in the collected sample and of the population in each city.

	Sample collected			Population		
Mode of the most frequent trip	**Bogota**	**Medellin**	**CDMX**	**Bogota**[5]	**Medellin**[6]	**CDMX**[7]
Car or Motorcycle	37%	32%	28%	33%	38%	30%
Taxi or TNC	8%	8%	12%	8%	9%	9%
Mass transit	55%	60%	60%	58%	53%	60%

[5] https://www.simur.gov.co/encuestas-de-movilidad
[6] https://www.metropol.gov.co/observatorio/Paginas/encuestaorigendestino.aspx
[7] https://www.inegi.org.mx/programas/eod/2017/

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