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Testing Microtransit's Added Value

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Acronyms

ABM	App-based mobility
BRT	Bus rapid transit
CFA	Confirmatory factor analysis
CFI	Comparative Fit Index
EFA	Exploratory factor analysis
ICT	Information and communication technology
LAC	Latin American and The Caribbean
RMSEA	Root Mean Square Error of Approximation
SEM	Structural equation models
SRMR	Standardized Root Mean Square
TLI	Tucker-Lewis index
TNC	Transportation Network Company
VMT	Vehicle miles travelled

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Abstract

Microtransit services are a midpoint between standard ride-hailing services and conventional bus fleets from public transit. Utilizing small buses or vans to provide on-demand shared transport, these services enable users to reserve seats, track their trips, and receive real-time estimates of pick-up and drop-off times. While public transit systems in the Latin American and the Caribbean (LAC) region are the subject of critical and often contentious policy debates with frequent references to user discontent and an overall decline in quality, microtransit is emerging as an alternative that could improve existing transit systems. They are argued to be an effective means to extend the coverage of transit services in transit deserts, by providing service in areas without transit routes and where investments in stations and infrastructure might not be cost effective. Despite its potential benefits, microtransit remains under studied in the LAC region. Based on survey data gathered for Barranquilla, Colombia, and Mexico City, Mexico, this research examines the added value of digital technology features in microtransit. This paper explores individuals' perceptions of the Information and Communication Technology (ICT) features present in microtransit and different variables mediating such perceptions. Employing factor analysis, and Structural Equation Models (SEM), ICT features are considered as latent variables and placed as the main outcome of the SEM. Other latent variables encompassing perceptions, such as the quality and safety of public transit, are also included in the model. Results indicate that individuals with pro-car attitudes and those who own cars are more likely to prefer ICT features in microtransit, suggesting potential for modal shift. Similarly, insecurity in public transit also explains favorable perceptions about the ICT features in microtransit. We also found that higher levels of technological savviness and being a ride-hailing adopter are related to increased valuations of microtransit.

Keywords: Microtransit, Ride-hailing, Public Transit, Technology, Structural Equation Models SEM.

JEL Classifications: 014, R42, R58, Z18

1. Introduction

The emergence of Information and Communication Technologies (ICT), such as smartphones, cellular data connectivity, and GPS, has spurred rapid evolution of passenger transport systems over the past two decades. By optimizing resources and empowering passengers with greater control over their trips, these technologies are argued to significantly enhance the efficiency and quality of transportation systems (Acheampong, 2021; Oviedo et al., 2022b). As a result, ICT facilitated the development of what is now known as App-Based Mobility (ABM), an umbrella term to describe services mediated through a mobile application. ABM includes services such as ride-hailing, bike-share systems, and e-scooters (Shaheen et al., 2020; Tirachini, 2020). Previous research on ABM has predominantly focused on ride-hailing, finding that its prevalence is higher among young, highly educated individuals and within dense urban settings (Alemi et al., 2018a; Tirachini, 2020). Recent works in the Global South show a strong gender dimension suggesting that women are more likely to use ride-hailing and rely more on this service to improve their travel security (Sabogal-Cardona et al., 2021; Scholl et al., 2021). Debates surrounding the regulation of ride-hailing services are still open in most countries where Transportation Network Companies (TNCs) have a presence. These debates provide a clear example of how ICT has generated changes in the transport landscape and called for the review of policy frameworks that govern passenger transport systems (Oviedo et al., 2021a).

A less explored topic in ABM research is app-based collective transport, also known as microtransit. Microtransit services utilize small buses or vans that operate as an on-demand alternative-where routes can adjust in real-time or can be fixed but adjusted more frequently than traditional public transit, based upon data on user preferences gathered through crowd sourcing, providing a hybrid service between public transit and ride-hailing (Fernández L et al., 2008; Flores-Dewey, 2019; Hall and Qureshe, 1997; Rissanen, 2016). Microtransit is frequently argued to offer a more user centered mobility solution for specific population groups, such as individuals residing in transit deserts, car-dependent users who are not inclined to use mass transit systems (Brown, 2019; Moody et al., 2021), and transit users willing to pay a higher fare to improve their commute quality. In Latin America, where marked spatial and economic inequalities and poor access to employment are prevalent across cities (Martínez et al., 2018; Scholl et al., 2024), the search for solutions to improve the coverage of collective transport services occupies a central role in policy and practice to narrow the gaps left by conventional public transit. Responses from the public and private sectors have included the development of microtransit pilots and startups.

This research, focusing on microtransit systems in Barranquilla (Colombia) and Mexico City (Mexico), assesses the subjective value residents place on ICT-related features of microtransit, considering variables affecting individuals' and social groups' attitudes toward collective transport. We hypothesize that, for both Barranquilla and Mexico City, ICT features incorporated in microtransit can address quality and insecurity challenges in public transit (Oviedo et al., 2022a; Rodas-Zuleta et al., 2022; Scholl et al., 2021) while providing a feasible alternative to reduce car-based trips. This paper thus examines the value of ICT microtransit features as a function of individual and transport-related characteristics and behaviors while also considering attitudes towards crime and insecurity in public transit, comfort and efficiency in public transit, and perceptions about car ownership, among other relevant factors.

Previous experiences with microtransit pilots in Europe and the United States over the past decade aimed to assess its efficacy in filling public transit gaps in underserved areas or extending the coverage of public transit serving first- and last-mile trips. Results from the pilots, however, are inconclusive, with microtransit benefits often insufficient enough to justify the costs. Even though the majority of public transit systems around the world are not financially self-sustainable, previous microtransit pilots often require significantly higher subsidies than other public transit alternatives (Haglund et al., 2019; Rissanen, 2016). While microtransit systems might cost-prohibitive in developed economies, they still might flourish in cities where existing public transit is mainly low-quality, informal, and insecure, as is the case in most cities in Latin America and the Caribbean (LAC). Moreover, its potential for reducing single occupancy vehicles trips and providing essential transport services to vulnerable and carless populations, two benefits that may warrant public subsidies, remains unexplored. By testing ICT features in microtransit, this research provides unique evidence for current policy debates in LAC cities about digital technologies' role in collective and public transportation.

2. Background

Microtransit refers to demand-responsive shared transportation services delivered through minibuses or vans, where users request rides through a mobile application (Oviedo et al., 2023; Shaheen et al., 2020). They are positioned in between ride-hailing and public transit. As ride-hailing, microtransit integrates various technologies such as mobile applications, GPS tracking, and fare management and payment, allowing passengers to access real-time information and make transactions effortlessly. Although ride-hailing can induce positive outcomes such as reduced car dependence, most ride-hailing trips will have only one passenger, and evidence of the effect on vehicles' miles travelled (VMT) is mixed (Cervero, 2017; Tirachini and Gomez-Lobo, 2019). Moreover, ride-hailing services are in most cases a premium service that is not economically accessible to individuals without the capacity to afford the fare. A fundamental difference between microtransit and ride-hailing is that in microtransit, collectively sharing the vehicle reduces the fare, allowing users to pay less.

Similar to public transit, microtransit passengers share a vehicle and pay a lower fare than if travelling using a ride-hailing or taxi service. Moreover, they do not have to experience burdens associated with car-based trips, such as looking for parking at the destination and paying for it. Even though microtransit is more expensive than public transit, by incorporating ICT into its operation, microtransit is expected to provide improved service while improving personal security (Flores-Dewey, 2019). Apart from the fare and the incorporation of technology, there are other contrasts between microtransit and public transit. For example, public transit operates under fixed schedules and routes, that are updated infrequently, while microtransit can more quickly adapt to and respond to user demand.

One of the modern microtransit pilots, Kutsuplus, implemented in Helsinki, Finland (Haglund et al., 2019; Rissanen, 2016) was an intelligent, demand-responsive transit alternative jointly developed between the private and public sectors that lasted from 2012 to 2015. According to the pilot's official final report, the service steadily increased its user base, reaching a total of 32,193 passengers by the end of the pilot. Similarly, the service went from no more than 20,000 trips during the first year of operation to almost 100,000 trips before its closure. In total, 56% of Kutsuplus users reported owning a private vehicle. Moreover, the service enjoyed high satisfaction levels, rating 4.7 out of five (Rissanen, 2016). Even though the final report acknowledges that before the launch of the service it was clear that substantial funding was needed, the subsidies required as a percentage of operation costs fell overtime as the popularity of the service increased (from nearly 100% to 80%). Nevertheless, given fiscal constraints of the government, and the need for significant subsidies (more than € 2 million only for the last year of operation) to keep Kutsuplus in operation, the service was discontinued. Another study evaluated the Kutsuplus pilot (Haglund et al., 2019), and even though it also found that demand for the service was increasing, other findings were that: i) it reported low vehicle occupancy (on average, 1.27 passengers per trip); and that ii) many trips appear to substitute car journeys. However, the authors note that this latter finding could also have the undesired outcome of replacing some walking and cycling trips given the short distances of the trips.

There have been other microtransit pilots in Europe and the United States (Westervelt et al., 2018) with mixed results. As a result, how to successfully implement microtransit remains a contested topic, with economic viability, effective contract design, regulatory environments, the definition of performance metrics, and the need for subsidies, at the core of the debate. A different trajectory has been observed in the LAC region. Before the Coronavirus pandemic, the startups Jetty and Urbvan in Mexico City were attracting attention, gaining ridership, and proving to be economically viable. A plausible explanation for this could be the dependence on semi-informal small buses in the city known as Jitneys (INEGI, 2017), which have no subsidies from the government and are considered a low-quality and unsafe alternative (Flores-Dewey, 2019). According to user surveys analyzed by Tirachini et al. (2020), Jetty passengers value specific attributes like advanced seat booking, increased security against theft, predictable trip durations, and travel time reliability.

Regulation plays a significant role in enabling or restricting the scale and coverage of microtransit operations in Latin America (Oviedo et al., 2023). Mexico City was the first city in the region to regulate TNCs, allowing them to coexist with public transportation services under different regulations (Puche, 2019). The Mexican regulatory framework categorizes TNCs as private transportation services, primarily addressing individual transport models such as Uber rather than collective ones. Nevertheless, the legislation's definitions are sufficiently broad to permit microtransit operators like Jetty to obtain permits as private operators (Flores-Dewey, 2019; Hernández Romero, 2018). Public transportation operators, including taxi and bus/jitney associations, exert substantial influence on regulations and restrictions concerning the operation of new models like app-based collective transportation services. These operators view emerging models as competition, necessitating negotiation and compromise between authorities and new transport companies (Flores-Dewey, 2019; Hernández Romero, 2018). Consequently, app-based collective transportation operators often collaborate with existing jitney and public transportation operators to ensure business success, driver and customer safety, and access to users, areas, or routes that would otherwise be geographically difficult to cover (Flores-Dewey, 2019; Oviedo et al., 2023).

3. Methodology

We selected the metropolitan area of Barranquilla, in Colombia, and the metropolitan area of Mexico City, in Mexico, as the case studies for this research. Despite being the core of their respective metropolitan areas, Mexico City and Barranquilla are cities of different scales and with contrasting transport and urban structures. The Mexico City metropolitan area population of nearly 20 million inhabitants comprises Mexico City and 57 other surrounding municipalities (INEGI, 2020). The Barranquilla metropolitan area includes Barranquilla and the co-urbanized neighbor municipality of Soledad, as well as the peripheral cities of Galapa, Puerto Colombia, and Malambo, generating an overall population of around 2.3 million individuals (DANE, 2019). In terms of mass transit infrastructure, Mexico City has a BRT system and a metro, while Barranquilla has a BRT system and no metro.

According to the Household Transport Survey 2017 (INEGI, 2017), there are 15.62 million daily trips in the Mexico City metropolitan area, of which 7.96 million (50.9%) are primarily completed in any available public transit alternative. Nevertheless, most of these trips (6.09 million) are made via “colectivos” or “jitneys”, a form of semi-informal public transit that are often low quality and insecure. In total, 20.2% of the trips in the Mexico City metropolitan area occur in private cars and one percent in motorbikes. Walking is central in the mobility of Mexico City, with 65.9% of the trips including walks as the primary mode of transport or as part of the trip chain (INEGI, 2017), meaning that the majority of the trips include activities such as walking to the transit station or from the parking location. The transit system in Mexico City faces several changes related to crime and gender-based violence (Dunckel Graglia, 2016; Dunckel-Graglia, 2013), and recent research is showing that this might be inducing a higher adoption of ride-hailing services (Oviedo et al., 2022a; Sabogal-Cardona et al., 2021; Scholl et al., 2021). The gender inequalities in the access and use of public transit extend to older adults. For example, compared to males, older females use public transit, walk and bike the least (Villena-Sanchez et al., 2022). Recent work highlighted that the intention to cycle in Mexico City is influenced by cycling attributes, attitudes to cycling, social comparison, and social image and prestige (Cepeda Zorrilla et al., 2019).

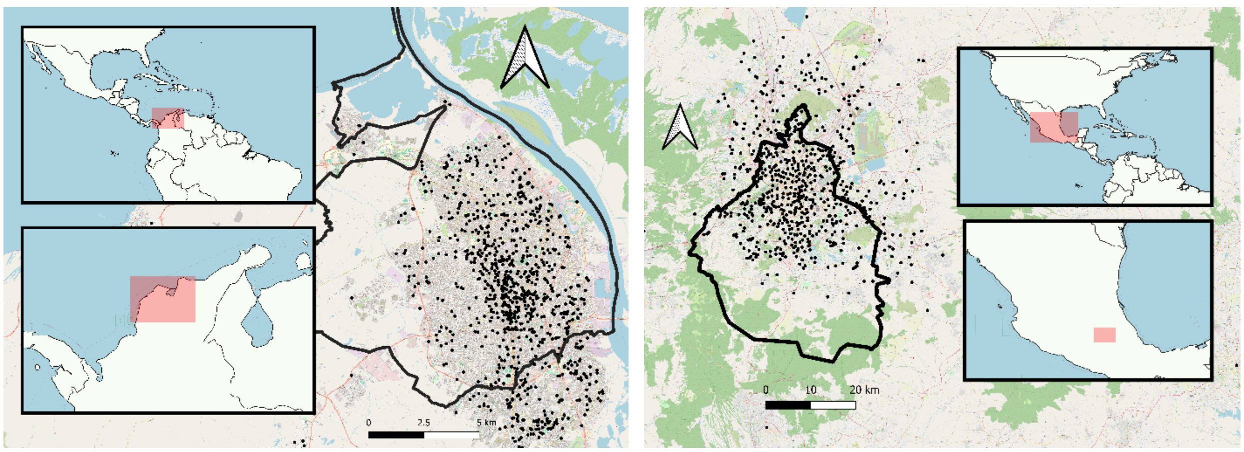
By 2022, most of the daily trips in Barranquilla were completed in public transit alternative: 28% in the bus system (including services such as “buseta”, “micro”, “ejecutivo”, and “colectivo”), 14% in the BRT, and 12% in the bus integrated transit system (YANHAAS, 2023). The use of active transportation is low, with only three percent of people walking and the other three percent using bicycles, something that contrasts with the modal share of private cars (13%), motorbikes (nine percent), and taxis (11%). Research in Barranquilla has focused on the low prevalence of walking and cycling trips (Arellana et al., 2021, 2020), finding that perceptions of the likelihood of being a victim of a crime or accident tend to outweigh the perceived economic and health benefits of cycling, resulting in individuals constrained from commuting by bicycle (Gutiérrez et al., 2021). Similarly, in the adjacent city of Soledad 67% of the trips are conducted in public transit, and even though car trips account for a small share (three percent), motorbikes account for 13% of trips. Walking and cycling trips account for approximately three percent of the trips (each) (Cifras y Conceptos, 2019).

As outlined in the literature review section, in the Latin American context, microtransit services have attracted attention mainly in Mexico City, where microtransit services have been operating for four years. Mexico City sets an ideal stage to study microtransit given that it is a place where microtransit is flourishing, as opposed to previous experiences in Europe and the United States. In November 2022, the Venezuelan company “La WaWa”, with a presence in Caracas, expanded its operation to Barranquilla and is focusing on the main employment hubs of the city. Barranquilla constitutes a relevant case study for two reasons. First, it enables the exploration of the evolution of microtransit in the early stages. Second, as a city at with a smaller population size than that found in megacities of Caracas or Mexico City, it provides interesting independent insights on the trajectory of microtransit at a different scale.

3.1 Data

We designed and distributed a survey in Spanish, the official language in Colombia and Mexico, adjusting the wording and tone of the questions according to the local culture. The questionnaire contained sections for demographics and household composition questions, perceptions about ICT features in microtransit, attitudes towards different urban and transport elements (see the discussion below about the latent variables), and a discrete experiment assessing under which pricing scenarios respondents are likely to switch their typical trip to microtransit. Results from the discrete choice models are not included in this paper. Data was collected between November 2022 and January 2023.

Figure 1. Distribution of the sample in Barranquilla (left) and Mexico City (right)



Source: Own elaboration

The questionnaire was administered through a computer, smartphone, or tablet connected to the internet. Pollsters equipped with tablets conducted face-to-face surveys in hotspots of economic activity. The study was also advertised on social network platforms (Facebook and WhatsApp). After checking the data quality, the final sample size was 1,100 for Barranquilla and 1,308 for Mexico City. Figure 1 illustrates that the place of residence declared by respondents in Barranquilla and Mexico City is evenly distributed in space, except for some neighborhoods at the northwest and west in Barranquilla.

Table 1 presents the main characteristics of the sample. We observe a gender imbalance, with 59% of respondents in Barranquilla declaring to be female, and 41% to be males; a reverse trend is observed for Mexico City, where 45% of individuals were females and 55% males. In Barranquilla, 52% of the respondents are between 31 and 50 years old, followed by people below 31 (29%). Individuals older than 50 account for 19% of the sample in Barranquilla. Mexico City also concentrated most respondents in the age cohort between 31 and 50 (49%). However, there is a higher presence of people below 31 years old (44%) and people above 50 accounts only for 7% of the sample. Following a similar pattern to the overall distribution of the population, 53% of respondents in Barranquilla are part of a medium-income household, 35% of a low-income family, and only 10% of a high-income household. Mexico City displays an entirely different pattern, with 75% of the sample declaring low-income.

Lastly, Table 1 displays the modal share for the most typical trip of survey respondents. More than half of the individuals in the survey use public transit for daily mobility (55% in Barranquilla and 73% in Mexico City). Private transport (car) accounts for 26% of trips in Barranquilla and 13% in Mexico City. Barranquilla's mode share includes special services (17% of the total) that represent trips made in private vehicles (often small buses) provided by large and medium companies interested in ensuring their employees can reach their facilities. Uber and InDrive are the main Transportation Network Companies (TNCs) offering ride-hailing services in Colombia, while Uber and DiDi are the most popular in Mexico. Interestingly, ride-hailing accounts for substantially more daily ridership (7% in Barranquilla and 8% in Mexico City) than taxis (1%). This mode share for ride-hailing is unusual since this kind of service is considered an excellent alternative for not regular trips (Sabogal-Cardona et al., 2021; Tirachini, 2020), such as health, leisure, or care trips but not for everyday commutes. Walking and biking only account for 2% of the typical daily trips.

Table 1. Sample description

	Barranquilla, Colombia		**Mexico City, Mexico**	
	Official statistics	Sample	Official statistics	Sample
Gender (%)				
Female	52%	59%	52%	45%
Male	48%	41%	48%	55%
Age (%)				
Young (<31 y/o)	34%	29%	24%	44%
Adult (31-50 y/o)	36%	52%	45%	49%
Elderly (>50 y/o)	30%	19%	31%	7%
Household Income (%)				
Low Income	57%	36%	51%	75%
Medium Income	33%	53%	35%	11%
High Income	10%	10%	14%	14%
Transportation mode (%)				
Private Transport	22%	26%	22%	13%
Public Transport	54%	55%	51%	73%
Special Service	-	17%	-	-
Taxi	11%	1%	13%	1%
Jetty - Urbvan	-	-	-	1%
Ride-hailing	-	7%	-	8%
Active transport (walking and cycling)	6%	2%	66%*	3%

Modal share for Barranquilla in the official statistics is derived from a yearly survey disseminated by a local agency while modal share for Mexico City is from the 2017 transport household survey. Moreover, data for Barranquilla refers to the main mode used in the trip and data for Mexico City refers to all the trip stages.
*: Walking trips for Mexico City include any type of walks such as walking to a transit station or walking to a parking spot. Therefore, modal share does not add to 100%.

Source: This study, using survey data and official statistics

3.2 Measuring attitudes towards and perceptions of ICT microtransit

We estimate subjective perceptions of and attitudes towards ICT microtransit features through the computation of latent variables[1], also known as constructs or factors (Brown, 2015; Kline, 2016). The survey included a section asking respondents to rate five statements about ICT microtransit features. We use these five statements as a mechanism to calculate a latent variable associated with ICT microtransit features. To the best of our knowledge, no previously proposed scale exists to study ICT perceptions in transportation. Therefore, our scale is also a contribution of this paper that, nonetheless, should be tested and adjusted to other geographic contexts and to other transportation alternatives. In a five-categories ordered scale (Completely disagree, disagree, nor agree neither disagree, agree, and completely agree), respondents were asked to rate the following statements: i) "I would love to have the opportunity to book a seat on transit using an app"; ii) "I like the idea of knowing and sharing the location of the vehicle I am using to travel"; iii) "knowing the license plate of the vehicle and information about the driver would make me feel safer"; iv) "knowing how much time the vehicle will take to pick-me-up is important"; and v) "calculating travel times is important for me." The first four items are used to generate the latent variable IT microtransit services, the main outcome variable of the model.

The model considers other latent variables hypothesized to impact ICT microtransit services and incorporated as regressors. These latent variables are technology affinity (Alemi et al., 2018b, 2018a), car attitudes (Acheampong et al., 2023; Moody and Zhao, 2020, 2019; Sabogal-Cardona et al., 2023), quality of public transit (Bertucci et al., 2022; Oviedo et al., 2022a), and security concerns in public transit (Acheampong, 2021; Jing et al., 2021; Ma et al., 2019). Table 2 presents the indicator variables used to compute all the latent variables. Mean values and standard deviation per city are also included. The questions for these other latent variables (except for security concerns in public transit) were asked using the same five-categories ordered scale mentioned in the previous paragraph. For security concerns in public transit, the survey asked respondents how often they worry about facing robbery or harassment in certain situations. The way we used to frame this question is a recommendation from fear of crime analysis (Jackson, 2005; Scholl et al., 2021), stating that asking the individuals to think in terms of frequency avoids the influence of transitory emotions. Even though the batteries and scales for these other latent variables are based on previous studies, the final wording are a proposal developed for this research.

We first employed an Exploratory Factor Analysis (EFA) to identify the underlying structure of and the relationships between variables, as well as to determine the number of factors needed to explain the observed covariation of the data. We employed eigenvalues-based methods including Kaiser-Guttman, the scree plot, and the parallel analysis. The results suggested the presence of the five hypothesized factors. Moreover, the factors in these tests showed that items' coefficients load strongly only on one factor and follow the expected pattern. Similarly, Alpha and Omega indices resulting from the eigenvalues methods indicate strong internal consistency and reliability, while the Kaiser-Meyer-Olkin factor adequacy measures indicate a high degree of

[1] The logic underlying the estimation of latent variables is that they exist and, even though it is impossible to make a direct measurement, they manifest through variables that can be directly measured and that receive the regular names of observed or indicator variables. Latent variables are responsible for the indicators' scores and the correlation among these indicators. Confirmatory Factor Analysis (CFA) is the method frequently used to calculate latent variables and is extensively employed in transport studies (Brown, 2015; Kline, 2016).

factorability. The Bartlett's sphericity test, used to confirm that relationships between variables in our dataset are strong enough to justify using factor analysis[2], were also significant.

To assess the goodness of fit measures of a CFA, several indices and cut-offs have been proposed (Brown, 2015; Kline, 2016). In this work, we follow a recommendation by Brown (2015) and collectively evaluate four indices: the Standardized Root Mean Square SRMR, the Root Mean Square Error of Approximation RMSEA, the Comparative Fit Index CFI, and the Tucker-Lewis index TLI. Recommended thresholds for good fit are less than 0.08 for SRMR, less than 0.06 for RMSEA, and values above 0.9 for TLI and CFI. We conducted an analysis of invariance per city that suggests that all of the constructs behave similarly. We also tested whether our model worked similarly across different cities, which is important for ensuring that our findings are comparable. We found evidence of configural invariance, metric (or weak) invariance, strong (or scalar) invariance, and residual (or strict) invariance. This analysis showed strong evidence that the key concepts we measured were understood and responded to in consistent ways across all cities.

Table 2. Summary statistics of latent variable indicators

	Barranquilla		Mexico City	
	Mean	Standard Error	Mean	Standard Error
Security concerns in public transit				
Being robbed while travelling	3.183	1.276	3.427	1.351
Being harassed while travelling	2.931	1.129	2.886	1.448
Being robbed while waiting for, or walking to, public transit	3.395	1.176	3.363	1.360
Being harassed waiting for, or walking to, public transit	3.064	1.174	2.968	1.464
Quality of public transit				
The fare is fair	3.005	1.078	3.267	1.134
The state of the vehicles is appropriate	2.668	1.047	2.644	1.186
The drivers are kind, and their service is good	2.944	0.948	2.730	1.144
The frequency is good	2.673	1.048	2.880	1.208
I can know my travel time accurately	2.687	1.099	2.683	1.224
Car attitudes				
Car is indispensable in my life	3.566	1.044	2.949	1.224
There should be more space for parking in the city	4.163	0.813	3.326	1.174
Building new lanes and roads is needed to solve mobility problems	4.170	0.813	3.545	1.174
Technology affinity				
I feel attracted towards virtual activities (for example, online shopping)	3.660	0.827	3.403	1.251
I am a regular user of electronic services (for example, Spotify, Netflix or Dropbox)	3.764	0.861	3.837	1.205
Mobile apps are important in my daily life	3.959	0.728	3.713	1.173
IT microtransit features				
I would love to have the opportunity to book a seat in transit using an app	3.963	0.830	3.776	1.220

[2] The Bartlett test is used to CFA to confirm that the correlation matrix is different from the identity matrix.

I like the idea of knowing and sharing the location of the vehicle I am using to travel	3.972	0.754	3.937	1.164
Knowing the license plate of the vehicle and information about the driver would make me feel safer	4.031	0.741	4.018	1.135
Knowing how much time my vehicle will take to pick me up is important	4.309	0.642	4.077	1.092

Source: Analysis of survey data collected for this study.

3.3 Framework for the statistical model

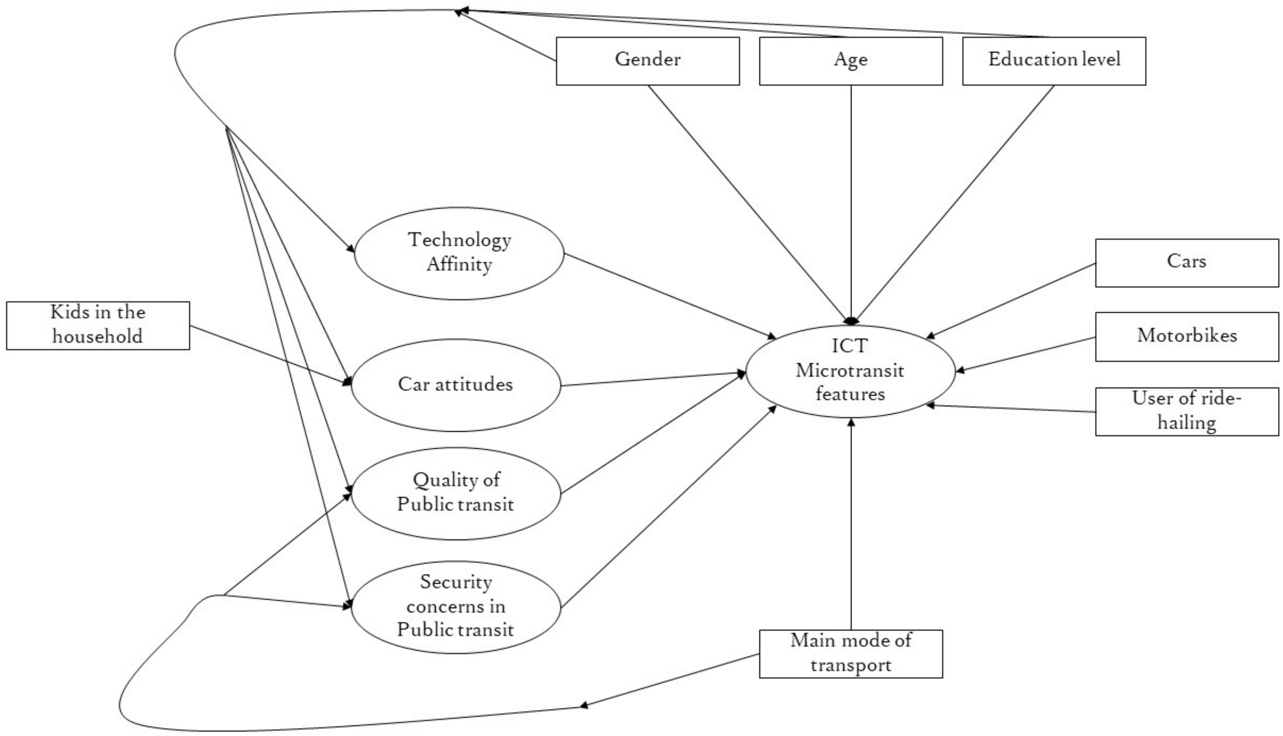
The proposed model extends the CFA to a Structural Equation Model SEM with five regression paths (see Figure 2). This SEM sets the hypothesis and theoretical framework we want to explore in this research and with the collected data. The primary regression, which is the core of this article, takes the latent variable ICT microtransit features as an outcome. The variable is regressed into the other four latent variables to establish if there is any statistically significant association. This regression controls for several demographic and household composition characteristics expected to influence the valuation of microtransit services.

Gender is included because in a context marked by crime and gender-based violence in public spaces and when using public transit, women would find a mechanism to commute safer in the technology incorporated in microtransit (Oviedo et al., 2022a; Scholl et al., 2021). Age is also considered under the assumption that younger generations are more likely to adopt new technologies and try new services (such as ride-hailing or microtransit) than people in older generations (Alemi et al., 2018a; Sabogal-Cardona et al., 2021; Tirachini, 2020). Similarly, different levels of education could facilitate the adoption of new technologies or the means to afford a service with a fare higher than the fare in public transit. In the model, we aggregate education level into three categories: low for no university (undergrad) education, medium for university education without a postgraduate degree, and high for university education with a postgraduate degree. Income or Socioeconomic Stratus SES are not included in the model, given that these variables were highly correlated with education.

The remaining independent variables in the ICT microtransit features regression are linked to transportation. The mode of transport regularly used for the most typical trip is considered because it can provide insight into which transport modes are more and least likely to be replaced by microtransit. Car and motorbike ownership are also included because having a private vehicle could reduce the likelihood of an individual using microtransit and/or perceiving its benefits. Lastly, whether the respondents are users of ride-hailing services is included in the model. Technology in ride-hailing is similar to the technology in microtransit, so previous exposure to ride-hailing may be associated with a preference for the ICT features associated with microtransit.

In the SEM portrayed in Figure 2, there are four additional regression paths for four additional latent variables. These other regressions complement the primary regression (ICT microtransit features). The variable *Number of children in the household* is hypothesized to affect environmental attitudes and car attitudes, given that people with children might be more aware of the implications of the ongoing climate emergency and, at the same time, depend on a family car. The transport mode used for the most typical trip is also included for the latent variables related to public transit.

Figure 2. Proposed Structural Equation Model



Source: This study

4. Results

Table 3 shows the main results for the CFA models. All standardized estimates of the factor loadings are significant. Moreover, all the goodness of fit proposed to assess the models are within the recommended thresholds. The SRMR is 0.043, the RMSEA is 0.051, the TLI is 0.992, and CFI is 0.994. Thus, it can be inferred that the measurement component is properly functioning.

After assessing the latent models, we move to SEMs. Table 4 shows the results for the regression path where ICT microtransit features are the outcome variable. In contrast, Table 5 displays results for the other four regressions that take all the other four latent variables as dependent variables. In both Tables 4 and 5, the estimate of the parameters is presented along with the standardized estimates. Standardized estimates are interpreted as the impact on standard deviations that the increase of one standard deviation in the independent variable has on the dependent variable. Moreover, standardized estimates are considered low if they are below 0.1, moderate between 0.1 and 0.2, and strong if higher than 0.2.

Table 3. Perception variables assessment results

	Estimate	Standard Error	Standardized Estimate
Security concerns in public transit			
Being robbed while travelling	1		0.869
Being harassed while travelling	0.823	0.045	0.715
Being robbed while waiting for, or walking to, public transit	1.082	0.013	0.94
Being harassed waiting for, or walking to, public transit	0.858	0.046	0.745
Quality of public transit			
The fare is fair	1		0.596
The state of the vehicles is appropriate	1.348	0.032	0.804
The drivers are kind, and their service is good	1.232	0.031	0.735
The frequency is good	1.276	0.031	0.761
I can know my travel time accurately	1.126	0.03	0.672
Car attitudes			
Car is indispensable in my life	1		0.622
There should be more space for parking in the city	1.35	0.04	0.84
Building new lanes and roads is needed to solve mobility problems	1.259	0.036	0.783
Technology affinity			
I feel attracted towards virtual activities (for example, online shopping)	1		0.709
I am a regular user of electronic services (for example, Spotify, Netflix or Dropbox)	1.15	0.022	0.814
Mobile apps are important in my daily life	1.097	0.022	0.778
IT microtransit features			
I would love to have the opportunity to book a seat in transit using an app	1		0.774
I like the idea of knowing and sharing the location of the vehicle I am using to travel	1.122	0.012	0.869
Knowing the license plate of the vehicle and information about the driver would make me feel safer	1.131	0.013	0.875
Knowing how much time my vehicle will take to pick me up is important	1.092	0.014	0.845

Notes: SRMR = 0.043, RMSEA = 0.051, TLI = 0.992, CFI = 0.994; All factor loadings are significant (p value < 0.01)

Source: Survey data collected for this study.

Focusing on the results for the regression of ICT microtransit features (Table 4), the regressors with the highest estimate parameter is technology affinity (standardized estimate of

0.689). This constitutes a natural finding given that individuals who are already more prone to adopt and see the value in new technologies, are expected to translate the same perceptions to transportation systems incorporating technology. We tested an additional specification of the model taking out the latent variable technology affinity in order to observe the behavior of all other regressors. Nevertheless, the parameter estimates, and their significance levels remained very similar to the original results.

The result for the latent variable car attitudes, with a positive estimate of 0.353, was completely opposite to our initial hypothesis. This result suggests that perceptions about the convenience and perceived virtues of car-based mobility do not reduce the likelihood of individuals valuing microtransit services. Aligned with the finding on car attitudes, there is a low but significant and positive effect of having one car (with reference to not owning a car) of 0.087 (standardized value) on valuing ICT microtransit features. This additional result implies that individuals with higher affinity for car-based mobility are more likely to have a higher valuation of microtransit as an alternate mode. The estimates for motorbike ownership are not significant.

Turning to perceptions of public transit, we can test two of the most relevant hypotheses in our research: the association between ICT microtransit features with public transit quality and perceptions of insecurity in public transit. The estimate for the quality of public transit is low (standardized value of 0.071), while the estimate for security concerns in public transit is strong (standardized value of 0.343). Other results included in Table 4 suggests that women, when compared to men, would be slightly less likely to perceive the benefits of ICT microtransit features (low standardized estimate of -0.062).

Regarding the effects of age, estimates in model 4 show that age cohorts between 40 to 50 years and older than 50 years have higher positive perceptions with similar and low standardized estimates of 0.069 and 0.065, respectively. The estimate for individuals younger than 30 years is close to zero and not statistically significant. The effect of education is also low, with the category for medium level of education having a standardized estimate of 0.055. Estimate for the highest level of education is not significant. Similarly, none of the categories included in the main mode of transportation produced significant coefficients.

Lastly, the estimate for the variable previous use of ride-hailing services is moderate (standardized value of 0.12), implying that exposure to ride-hailing might hinder usage of microtransit. Also, this result shows that ride-hailing exposure could familiarize individuals with technology similar to the technology incorporated in microtransit.

Table 4. SEM results – ICT microtransit features (main outcome variable)

	Est.	SE	Std. Est.
Technology affinity	0.792***	0.021	0.689
Car attitudes	0.491***	0.03	0.353
Quality of public transit	0.093***	0.027	0.071
Security concerns in public transit	0.318***	0.023	0.343
Gender			
Male	ref	ref	ref
Female	-0.099**	0.034	-0.062
Age (years)			
<30	0	0.039	0
30 to 40	ref	ref	ref
40 to 50	0.144**	0.051	0.069
>50	0.166*	0.066	0.065
Education level			
Low	ref	ref	ref
Medium	0.093*	0.036	0.055
High	-0.029	0.054	-0.012
Main mode of transportation			
Car	ref	ref	ref
Motorbike	-0.06	0.093	-0.019
Public Transit	-0.052	0.058	-0.031
Walking/Cycling	-0.105	0.109	-0.02
Taxi/ride-hailing	0.147	0.078	0.053
Other	0.02	0.089	0.005
Cars			
None	ref	ref	ref
One	0.149***	0.042	0.087
More than one	-0.003	0.06	-0.001
Motorbikes			
None	ref	ref	ref
One	-0.064	0.045	-0.032
More than one	-0.201	0.127	-0.037
User of ride-hailing			
No	ref	ref	ref
Yes	0.243***	0.044	0.12

Est.: Estimate; SE: Standard Error; Std. Est.: Standardized Estimate
Significance levels: <0.05(*), <0.01(**), <0.001(***)

Source: Survey data collected for this study.

In the other regressions outlined in the path diagrams of Figure 2 and presented in Table 5, we can see that being a woman (compared to being a man) is not significantly associated with technology affinity, but there is a positive and low association with car attitudes (standardized estimate of 0.062). Similarly, there is no gender association with the quality of public transit variable, but there is a strong estimate for security concerns in public transit (standardized value of 0.226).

Estimates for age on technology affinity show the expected results, with the respondents being the least technology savvy as they age. Taking the age cohort between 30 and 40 as the reference category, there is a negative association between technology affinity and the age cohort, 40 to 50 years. Being older than 50 has a moderate negative impact on technology affinity (standardized estimate of -0.106). Interestingly, membership to the age cohort older than 50 is associated with pro-car attitudes (standardized estimate of 0.119).

We assigned the low-level category as the reference category for the variable education level. Results show that having medium to high levels of education is associated with technology affinity (standardized values of 0.097 and 0.121, respectively). This result points to inequalities in access to and knowledge of emerging technologies. For the quality of public transit variable, the medium category shows a negative association (standardized estimate of -0.102), and the high category shows no statistically significant association. The estimated effects of education level on the security concerns in public transit are not significant. Unexpectedly, none of the categories associated with the main mode of transportation were associated with security concerns in public transit. On the contrary, most categories associated with the main mode of transportation have a significant estimate of the quality of public transit. The only exception is taxi or ride-hailing (no significant estimate).

Table 5. SEM results– Path regressions for the other latent variables

	Technology affinity		Car attitudes		Security concerns in public transit		Quality of public transit	
	Est.	SE	Est.	SE	Est.	SE	Est.	SE
Security concerns in public transit	---	---	---	---	---	---	0.026	0.037
Gender								
Male	ref	ref	ref	ref	ref	ref	ref	ref
Female	-0.033	-0.024	0.071***	0.062	0.39***	0.226	-0.03	-0.024
Age (years)								
<30	-0.01	-0.007	-0.09***	-0.076	0.067	0.038	0.007	0.005
30 to 40	ref	ref	ref	ref	ref	ref	ref	ref
40 to 50	-0.19***	-0.106	0.017	0.012	-0.064	-0.029	0.008	0.005
>50	-0.336***	-0.152	0.119*	0.065	0.012	0.004	0.09	0.046
Education level								
Low	ref	ref	ref	ref	ref	ref	ref	ref
Medium	0.143***	0.097	---	---	0.27***	0.147	-0.102***	-0.078
High	0.249***	0.121	---	---	0.215***	0.085	-0.049	-0.027
Kids in the household								
None	ref	ref	ref	ref	ref	ref	ref	ref
One	---	---	0.028	0.022	---	---	---	---
More than one	---	---	-0.078	-0.046	---	---	---	---
Main mode of transportation								
Car	ref	ref	ref	ref	ref	ref	ref	ref
Motorbike	---	---	---	---	-0.122	-0.035	0.154*	0.063
Public Transit	---	---	---	---	0.078	0.043	0.285***	0.222
Walking/Cycling	---	---	---	---	0.168	0.03	0.224**	0.056
Taxi/ride-hailing	---	---	---	---	0.088	0.029	0.101	0.048
Other	---	---	---	---	-0.242	-0.054	0.204*	0.065

Est.: Standardized Estimate; SE: Standard Error; Significance levels: <0.05(*), <0.01(**), <0.001(***); SRMR = 0.077, RMSEA = 0.061, TLI = 0.988, CFI = 0.969; All factor loadings are significant (p value < 0.01)

Source: Analysis of survey data collected for this study.

5. Discussion

The findings of this study are consistent with critical aspects of the literature on ABM and microtransit, particularly in Latin American and Caribbean (LAC) countries (Oviedo et al., 2022a; Scholl et al., 2021; Tirachini, 2020). The results reveal that individuals with high technology affinity are more inclined to have favorable perceptions of ICT features in microtransit services (standardized estimate of 0.689 that translates into an elasticity of 1.2%). This finding supports the notion that technology-driven solutions in public transportation can appeal to specific users' groups, as suggested in previous research (Alemi et al., 2018a, 2018b; Oviedo et al., 2021b). The result for technology affinity was expected, given that individuals engaged with technology probably already perceive its importance in other spheres of their lives. Therefore, they are more likely to extrapolate such value once transport systems incorporate technology.

There are two main takeaway messages from this research not previously reported in other studies. The first is that people with pro-car attitudes also are more likely to express an affinity for microtransit technology. We were expecting a negative estimate for car attitudes based on the assumption that cars might act as a deterrent to seeing the value of microtransit and that individuals attracted to car-based mobility might not prefer other shared alternatives. Yet the results suggest the opposite effect.

The above could be interpreted in two complementary and related ways. On the one hand, car-based mobility creates a safe, high-quality form of travel that is unavailable in other alternatives, particularly in public transit. Nevertheless, ICT features in microtransit may be perceived as a tool that improves safety and quality to the levels that car-based users are used to experiencing (Moody et al., 2021; Sabogal-Cardona et al., 2023). On the other hand, car ownership and car dependence could be, to some extent, and, in some cases, an obligatory financial burden. This means that some individuals would prefer to avoid completing trips in private vehicles and having to own and sustain a vehicle; but for them, the car is the best alternative in terms of coverage, convenience or personal security. Nevertheless, the alternative of microtransit services and the technology incorporated in microtransit might make them feel similar levels of coverage, convenience and personal security, resulting in a potential reduction of car ownership and car dependence. This is an important finding for policy and practice as it suggests that modernizing and providing higher-quality public transit alternatives in key markets can positively influence private vehicle users' attitudes towards collective transport. For example, transit deserts tend to be car-dependent areas where microtransit could expand the coverage of public transit systems.

The second main takeaway message from the findings presented in Section 4 is that individuals experiencing higher levels of fear of crime when travelling by public transit are, at the same time, the segment that best perceives the added value of the ICT features in microtransit. This result confirms that technology is a mechanism to improve personal security in transportation, something already highlighted in previous ride-hailing studies (Acheampong, 2021; Oviedo et al., 2022a; Scholl et al., 2021). For example, individuals perceiving higher risk could see value in booking a trip and a seat in advance, tracking their route, and knowing trip details (driver information, pick-up time, arrival time). Interestingly, service quality is less relevant than crime-related concerns in public transit systems. As such, a key priority for policymakers and public authorities in charge of public transit, particularly in cities with high incidences of crime, such as many large cities in Latin America, is to develop interinstitutional partnerships to improve personal security in public transport.

The research also adds nuance to the interactions between different forms of ABM in the local market. For instance, finding that prior exposure to ride-hailing services has a moderate impact on positive perceptions of microtransit suggests that familiarity with technology-enabled transportation services can facilitate the adoption of collective services enhanced by digital technologies. This finding aligns with the literature on shared mobility and its potential to complement traditional public transit systems (Barajas and Brown, 2020; Hall et al., 2018). Even though ride-hailing research has, across several international studies, consistently found that younger generations are more likely to engage with ride-hailing, we found the opposite in the case of microtransit. Our interpretation of this relates to the results about car attitudes and car ownership. Older generations seem more likely to look for alternatives that would reduce their reliance on private cars.

6. Conclusions

This research examined the subjective value residents of Barranquilla and Mexico City place on ICT-related features of microtransit. We found that individuals with pro-car feelings also have more positive feelings about technology in collective transport services (standardized estimate of 0.353 and elasticity of 0.7%). These individuals might perceive microtransit as a means of maintaining a high-quality mode of travel while potentially reducing the financial burdens associated with car ownership. These findings relate only to the perceptions of technological features of the service and not necessarily individual mode choices. Significantly, public transit security concerns also strongly correlate with positive perceptions of ICT features in microtransit services (standardized estimate of 0.343 and elasticity of 0.5%). The study also reveals that age, gender, and education level play significant roles in public transit technology affinity, environmental attitudes, car attitudes, and security concerns.

The paper's findings underscore the role of demographic factors in the design, promotion, and operation of microtransit services. Furthermore, they suggest designing public engagement mechanisms targeting specific demographics that can increase ridership among older and car-captive users. The latter are relevant targets for policies targeting a transition to more sustainable modes of transport from private vehicles. Furthermore, closing gaps in ABM adoption, particularly in technology-enabled collective transportation, requires purposeful policy and market actions such as improving women's affinity with technology and supporting access and familiarity with ICTs in public transit.

The research also points to key areas for further investigation. First, it is relevant to delve further into women's attitudes and perceptions that can unpack these findings through an intersectional perspective. Similarly, future analysis should consider the specific pre-conditions of socially disadvantaged groups and their barriers to capture benefits from ICT features in microtransit and other forms of transportation. Second, subsequent studies should build on the positive association between car attitudes and ICT microtransit features reported in this paper to explore how to design ABM systems that are attractive to car users. Moreover, future research could conduct a deeper analysis of security concerns and crime prevention in public transit by leveraging ICT. Research in similar contexts can help better understand the relationship between car attitudes and microtransit adoption, particularly across income groups, and incorporate geographical characteristics of places of residence and trips, considering the high levels of socio-spatial segregation in cities like Barranquilla. Third, additional analysis of the role of demographic factors in the perception and adoption of microtransit services is needed to develop tailored strategies for increasing ridership among different groups. Examining the impact of various ICT features in microtransit services on user satisfaction and overall system efficiency can help guide the development of future technologies and services in the sector. In addition to this, exploring the potential of integrating microtransit services with other forms of transportation, such as public transit and ride-hailing services, can contribute to creating more comprehensive and efficient urban transportation systems. Lastly, it is important to highlight that this article shows that the demand for the multiple technological features incorporated in microtransit services are associated with problems of quality and security in public transit, as well as with pro-car attitudes and car ownership. Nevertheless, how these technological features might contribute to the wider adoption of microtransit services should be explored in further research.

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