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Time use decisions in vulnerable urban communities when implementing innovative transport alternatives

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ABSTRACT

Travel time savings have been the most important benefit included in transport project assessments over the last decades. However, understanding how individuals allocate this saved time after implementing transport projects is crucial, as time is a finite resource and performing more pleasant activities may impact their well-being. Large urban interventions, such as the implementation of the first cable car line in a deprived community in Bogotá (Colombia), impact how residents around the project allocate their time. We studied their time-use allocation by estimating a discrete–continuous extreme value (MDCEV) model, by combining data collected before and one year after the project implementation, to represent time-use decision changes in the study area. The results show participation and duration of different activities changed after the project implementation. The cable car increased the probability of participating in work, study, and carrying/collecting activities. It also decreased the duration of travel activities. The cable car also increased women's time allocation to education and paid work. Overall, reduced travel time allows for more time for leisure and recreational activities. Understanding how individuals allocate their time is particularly relevant for policymakers to inform policies related to transport. This study offers valuable insights into both model development and data collection methods and the understanding of the mechanisms of time-use decisions.

1. Introduction

Transport projects have traditionally been evaluated based on travel time savings, which account for up to 80 % of the benefits that justify such investments (Mackie et al., 2001). However, it is not well-known how these savings are utilized, particularly in vulnerable communities; where there might be trade-offs between travel time and leisure, work, study, and other activities (Jara-Díaz and Contreras, 2024). In addition, time is a finite resource and economic inequality fosters people's perception of time poverty (Zhao et al., 2023). The significance of this matter stems from the fact that current evidence indicates that transport projects' time-saving benefits tend to deliver higher benefits than similar initiatives that cater to excluded and disadvantaged communities in a cost-benefit assessment (Martens and Di Ciommo, 2017). Nonetheless, such evaluations might overlook the value of free time, given that the time saved during travel can be utilized for enjoyable and well-being purposes, despite leisure is much more valuable in higher-income countries, possibly due to longer commuting times and unstable jobs in developing economies (Jara-Díaz et al., 2008).

In communities facing limited financial and time resources due to demanding work schedules and high commuting times, investigating the complex relationship between transport options, time use patterns, and travel decisions is important (Jara-Diaz, 2020). Therefore, the time allocation for marginalized populations is a critical issue that requires attention through initiatives and public policies that promote equality, particularly gender equality, given that women are often responsible for work, housework, and care work, as is the case in Latin American cities (Jara-Díaz et al., 2013; Murillo-Munar et al., 2023). It is crucial to analyze in detail the time saved in transport to identify the general benefits of (better) time use resulting from the implementation of a transport project.

However, this is rarely addressed in the literature, particularly in Global South cities. An in-depth analysis of how public investments affect time use is essential, particularly in public transport project implementation in disadvantaged and vulnerable areas. Travel time savings could be spent on more pleasurable activities, such as leisure,

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thereby improving subjective well-being (Guzman et al., 2023a). Hence, understanding individual time-use decisions is necessary since transport-related choices are directly linked (Jara-Díaz and Rosales-Salas, 2017). Specifically, the introduction of a new transport alternative can significantly alter individuals' time-allocation decisions, affecting their travel behavior and daily activity patterns. Therefore, policymakers and transport planners should develop accurate tools that account for the nuances of time allocation decisions.

This paper aims to provide an empirical basis for describing and explaining individual time allocation due to the implementation of a large urban intervention with an alternative public transport line in a vulnerable and historically marginalized area using a panel travel diary dataset. We analyzed the time use before and after implementing a new cable car in Bogotá (Colombia) in a peripheral poor community with low accessibility levels. By conducting surveys, and travel diaries and examining time-use data with community members, we aim to gain insight into how individuals allocate their time after the new public transport line was implemented. We seek to understand the impact of this intervention on time use and whether the project made residents more likely to perform some activities using a quasi-experimental natural experiment.

We estimated a multiple discrete–continuous extreme value (MDCEV) model (Bhat, 2008, 2005) using data collected before and one year after project implementation to represent time-use decisions. We considered systematic taste variations in the discrete and continuous model components to explore differences in the types and lengths of activities, examining observed preference heterogeneity regarding gender and cable car use. This research contributes to the broader literature on time use and provides practical implications for policymakers and practitioners.

2. Time use and travel

Time-use research has attracted interest from various disciplines, including economics, sociology, and transport (Bath and Koppelman, 1999; Harvey and Pentland, 2002). Understanding how individuals allocate their time to evaluate policy interventions and predict demand for goods and services that have significant implications for individuals and society is crucial. In recent years, the assessment of changes in time use within transport research has received increasing attention (Calastri et al., 2017; Farber and Páez, 2011; Lyons and Urry, 2005; Spinney et al., 2009). While travel time saved remains a crucial element of transport project assessment, recent studies have demonstrated that time savings can be utilized for activities that enhance well-being, such as leisure or additional sleep time (Jara-Díaz and Rosales-Salas, 2020) with deep gender differences (Havet et al., 2021; Jara-Díaz et al., 2013; Sweet and Kanaroglou, 2016). Time-use research serves as an essential tool for comprehending how individuals allocate their time and the factors that influence such distribution. This review explores the current state of time-use research and its potential application in supporting large urban interventions.

Over time, time-use data collection has evolved from traditional activity diaries or Origin Destination surveys to modern technology-based methods, such as GPS tracking and smartphone apps. Traditional travel diary studies rely on self-reported data from participants over a specific period, typically 24 h. Despite its limitations, such as memory bias and underreporting of specific activities, this method still continues to be used in regions with limited access to technology (smartphones and the internet). This is especially true among older individuals with lower education and income levels. Moreover, travel diaries provide critical data on activities that often fall under the purview of women, such as housework, care, and voluntary community-oriented work (Budlender, 2007).

The literature on time-use research identifies two distinct approaches: descriptive and modeling. Descriptive analysis is used to classify activities (As, 1978) and examine how people allocate their time (Adkins and Premeaux, 2012; Benvin et al., 2016; Lyons and Urry, 2005). On the other hand, modeling approaches focus on time-use decisions with a view to activity choice (Zhang et al., 2005). In addition, methods like the Hensher Equation, Willingness-To-Pay, and Cost Savings Approach have also been used to value business travel time savings, but no single method has emerged as the definitive solution (Wardman et al., 2015). Recently, the most widely recognized modeling approach for time-use decisions is the multiple discrete–continuous extreme value (MDCEV) models (Bhat, 2008, 2005). MDCEV models facilitate the simultaneous study of discrete and continuous choices, thereby capturing both observed and unobserved preference heterogeneity (Bernardo et al., 2015; Bhat, 2008; Castro et al., 2012; Chikaraishi et al., 2010; Palma et al., 2021; Pellegrini et al., 2021).

Bhat (2005) initially proposed the first closed form of an MDCEV model, which has since undergone various extensions, including the generalized extreme value and mixed form models (Bhat, 2008), the nested form (Pinjari and Bhat, 2010a), and multiple constraints analysis (Castro et al., 2012). The MDCEV model allows for the simultaneous consideration of multiple alternatives that do not necessarily substitute for each other perfectly (Calastri et al., 2017). The model assumes that individuals choose among alternatives based on their utility function, which comprises two components: the deterministic component that reflects underlying preferences and the stochastic component that captures unobserved factors affecting choice. The deterministic component is generally estimated using regression models (linear or nonlinear), while the stochastic component is modeled using the extreme value distribution.

Time-use research has expanded to encompass a more comprehensive range of activities, such as leisure activities (Calastri et al., 2017), travel (Farber and Páez, 2011), nonwork-related activities (Pinjari and Bhat, 2010a), or health-related activities (Christian, 2012). This broader perspective facilitates a more thorough understanding of how individuals allocate their time. MDCEV models have also found wide-ranging applications in various domains, including transport (Calastri et al., 2022; Jian et al., 2017), tourism (Saxena et al., 2023), energy consumption (Pinjari and Bhat, 2021; Yu and Zhang, 2015), vacation travel (LaMondia et al., 2008), and freight transport (Cantillo et al., 2018). The MDCEV models have demonstrated better prediction accuracy and parameter estimation than traditional discrete choice models. The most extensively researched field has been on time-use decisions, activity choices, and duration (Calastri et al., 2017; Palma et al., 2021). The broader focus on nonwork-related activities has provided a more holistic understanding of time-use patterns (Jara-Díaz et al., 2008).

Several studies have employed MDCEV models to examine various aspects of travel behavior. For example, Varghese et al. (2020) studied how crowding in Tokyo's rail systems is related to discrete–continuous choices in different multitasking activities, such as reading, talking, and ICT-dependent leisure activities. Calastri et al. (2022) found that for train passengers in the UK, activity choice and duration during travel are influenced by both trip and passenger characteristics, particularly the day/time of the trip, trip purpose, and ticket type. Another interesting issue is the lower frequency of out-of-home activity participation among low-income adults without access to a car in developed countries in Europe and North America, especially in activities with high subjective well-being (Morris et al., 2020). Improved access to the public transport system in developing countries can potentially enhance participation in productive and enjoyable activities for the population.

Such research provides valuable information that can inform the design of public policies that support economic growth, health, and social welfare. In the context of implementing a public transport line together with the improvement of the built environment in a vulnerable community, where willingness to work always decreases with travel time and increases with committed expenses (Jara-Díaz and Contreras, 2024), time-use research can identify gaps, current time-use patterns, assess the impact of the new project, and inform public policy decisions. Understanding the patterns of men and women is crucial due to the high prevalence of time poverty. Time poverty has important repercussions for women's economic opportunities and health (Hyde et al., 2020).

In this study, we hypothesized that the implementation of a cable car in the poorest community of a large city would result in travel time savings, prompt people to perform different activities from those typically done before the project and alter the time allocated to several activities. Specifically, evaluating the time-use allocation before and after the project implementation is a novel practice that can support the more specific benefits of urban transport interventions. This evaluation can assist in investment appraisal by providing insights into time-use changes and activity participation, which have seldom been analyzed in vulnerable communities.

3. The project: An aerial cable car for transport

The evaluated public transport project, named TransMiCable, is an aerial cable system inaugurated in December 2018. This cable car system consists of a single line of 3.43 km, 4 stations, and 163 cabins that connect a historically deprived and excluded area with the city's integrated public transport system. It is connected to a terminal station of the Bogotá Bus Rapid Transit (BRT) system named *Portal Tunal* (see Fig. 1). Encompassing more than just a transport alternative, TransMiCable was implemented together with multiple urban development interventions in the area of influence, which had social urbanism and a participatory process with members of the community as their pillars, along with the intersectoral work of Bogotá institutions. The projects included facilities for recreation and cultural activities, such as renovated public parks, a historical museum, a library, and two recreation, culture, and sports centers; community centers; local markets; a tourism office; and a civil service office (Sarmiento et al., 2020).

The project is located in the southwest of Bogotá, in a district named Ciudad Bolívar, where 88.8 % of the population does not meet their minimum consumption needs and 10.9 % live below the poverty level. Of the approximately 155,380 residents in the area of influence of the cable car, the vast majority of households are low and very low-income, with very low levels of vehicle ownership. Of the resident population, approximately 28 % are workers and 43 % are students. Of the 2.05 trips/day that each person made on average, only 4 % are by car/motorcycle, 37 % by public transport and paratransit, and 58 % by walking. Cycling is rarely seen, due to the steep slopes of the terrain in the area. The population studied has a mean age of 45 and a higher proportion of females. Most of the population has primary and secondary education and belongs to the lowest socioeconomic strata (SES) zones 1 and 2 (Cantillo-García et al., 2019). They also report household incomes below the minimum monthly legal wage. Overall, the population exhibits limited variability in key demographic characteristics.

The studied area is shown in Fig. 1 and comprises households within an 800-m buffer around each of the current cable car stations. In this area of influence, the motorization rate is about 0.07 cars/household (the average in Bogotá is 0.33 cars/household), an average household income of USD 380 (USD 700 for the city), and the modal share of car/moto is 4.0 %, public transport is 61.5 %, 6.4 % is a mix of informal transport and public transport, and the rest is a combination of active transport with either private or public transport. The average travel time is high: 145 min, while the city's average travel time is 52 min.

Before the project, a typical peak hour journey between the *Portal Tunal* and *Mirador del Paraíso* (the highest cable car station) could take up to one hour, so the cable car offers a saving in travel times of almost 80 %. The most used transport modes before were buses and informal transport. Fig. 2 shows that the average travel time was reduced for TransMiCable users who had long trips. This data represents the changes in travel times to mandatory activities for those who reported having used the TransMiCable on a typical day. When the trips were broken down, it was observed that the in-vehicle time was reduced by 11 min, but the waiting time, which has a significant negative effect on users, was reduced the most. However, there was an increase of 4 min on average walking time to access the cable car.

As observed, the cable car offers a nearly 15 % reduction in travel time, saving valuable time for commuters. Regarding non-mandatory trips, the average travel time before the project was 22 min. With the TransMiCable, the average travel time is 17 min. This is a reduction of 17 %. This reduction was the most significant benefit expected and perceived by the community before and after the implementation of the project (Guzman et al., 2023b). The success of this system depends on community adoption, and understanding how individuals allocate their time can be critical to its success..

4. Data and methods

This paper aims to investigate the decision-making process behind time usage, which involves selecting the type of activity to be performed and determining the amount of time to be allocated to that activity. Given that time is a finite resource, individuals face a constraint in choosing between various alternative activities that are available to

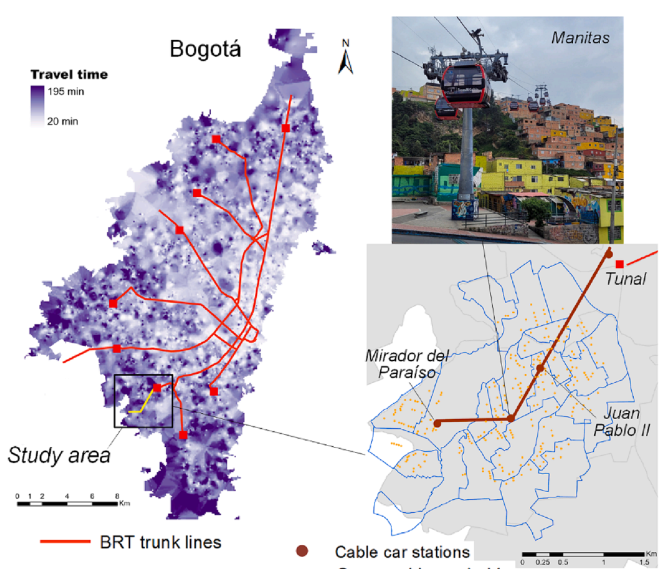

Fig. 1. Study area.

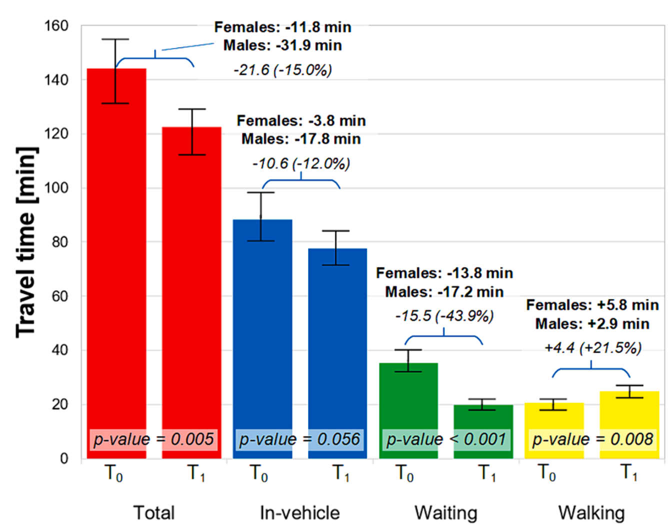

Fig. 2. Average travel time in the study area (before T0 and after T1) of participants reporting the use of TransMiCable for mandatory trips.

them (Hendel, 1999). This trade-off between competing activities is typically related to the quality of the chosen alternative (Bhat, 2005). To achieve this objective, we collected information through travel diaries in a subsample of the study population from a panel survey conducted both before and after the implementation of TransMiCable. We then employed the MDCEV approach to analyze the time-use decisions of individuals, accounting for various socioeconomic factors, such as age and gender, while also controlling for activity participation and time allocation. We also included other control variables, such as income, household size, and vehicle ownership, but due to the sample's homogeneity, we observed no significant differences.

4.1. Data collection

This study examines the travel patterns of a subsample of adults without cognitive disabilities living within an 800-m buffer zone around each cable car station. A household panel survey was conducted at two points in time, before and after project implementation, which includes socioeconomic information, travel patterns, and travel diaries. The study area is larger than traditional walking distance standards used in transport studies because low-income individuals in this context would walk more to access the transport system (Guzman et al., 2020).

The data collection process involved multistage sampling, including the selection of blocks with a probability proportional to the density of properties, the systematic selection of every third home, and the random selection of adults. Participants were recruited from 225 residential blocks within the intervention area. Specific information about the timing, destination, purpose, and transport model was collected through a paper-based open-response form (Sarmiento et al., 2020). However, confusion in filling in blank spaces generated problems. The data collection process was laborious due to the low educational level and poor writing skills of the respondents; interviewers reviewed the travel diaries with the respondents to clarify the information in them.

The travel diaries were handwritten on a printed table where each row provided information on a single trip. An open-response format was used in the diaries, increasing the richness of data related to the trips carried out by the sample. Participants had to fill in the blanks of six printed columns following the header instructions on how to communicate the information. The column headers were: "I started my journey at," "I went to," "I traveled on," "Using this route," "I arrived at," and "Approximate arrival address." The information provided in those columns was used as a descriptor, schedule, location, and transport mode used for each activity, as shown in Fig. 3.

Although an example was included in the first row and participants were asked to report eight (8) days in travel diaries, only an average of four (4) days were reported. The first wave collected baseline data before implementing the project between August and October 2018 (T0 henceforth). Then, we collected follow-up data one year after the project inauguration, namely between July 2019 and March 2020 (T1).

4.2. Data processing

Upon completing the data collection process, the travel diaries underwent further processing for analysis. The data processing entailed six stages: digitization, information normalization, correction, elimination, activity classification, and database consolidation. Initially, the diaries were digitized and consolidated into a singular table containing individual and travel diary identifiers. Next, the information was examined to standardize the reported trips into aggregate descriptors. The third stage involved rectifying trips with missing start- or end-time information. The most common error discovered during this stage was the lack of time in a 24-hour format. Subsequently, the data were reviewed to eliminate conflicting information, such as incomplete travel duration or descriptors. Data digitization, normalization, correction, and elimination took several months.

In the fifth stage, activities were deduced based on trip information and classified based on the time-use literature. The categorization employed in this research comprised three activity groups: location-dependent activities, instrumental activities, and expressive activities. The location-dependent classification exclusively considered the location where the activity occurred (Bhat and Misra, 1999; Calastri et al., 2017; Chikaraishi et al., 2010), which included staying at home as an activity. According to As (1978), instrumental activities are those that are either paid or hired (Chikaraishi et al., 2010) and mandatory (Jara-Díaz and Rosales-Salas, 2017). The instrumental activities examined in this analysis consisted of studying, errands, travel, delivery/pick-up (committed time), and work (contracted time). Lastly, the category of expressive activities included basic (physiological) needs (As, 1978) and leisure activities, including socialization (Calastri et al., 2017) and leisure (Chikaraishi et al., 2010). In this study, leisure activities were the only expressive activities considered due to the lack of information on basic needs.

The sample data allowed us to categorize exercise as an activity, similar to Palma et al. (2021). Finally, a category labeled as "others" was included to complete the 24-hour daily observation required for each record. This category addressed the issue created by the fact that most data from activity diaries did not span the entire 24-hour day. In summary, the activities were classified into work, study, stay-at-home, travel, leisure, errands, exercise, carry/collect things/people, and others, following the literature on activity time allocation (Bhat and Misra, 1999) and activity type and duration (Calastri et al., 2017).

The travel diary data was then exported to a database, where each

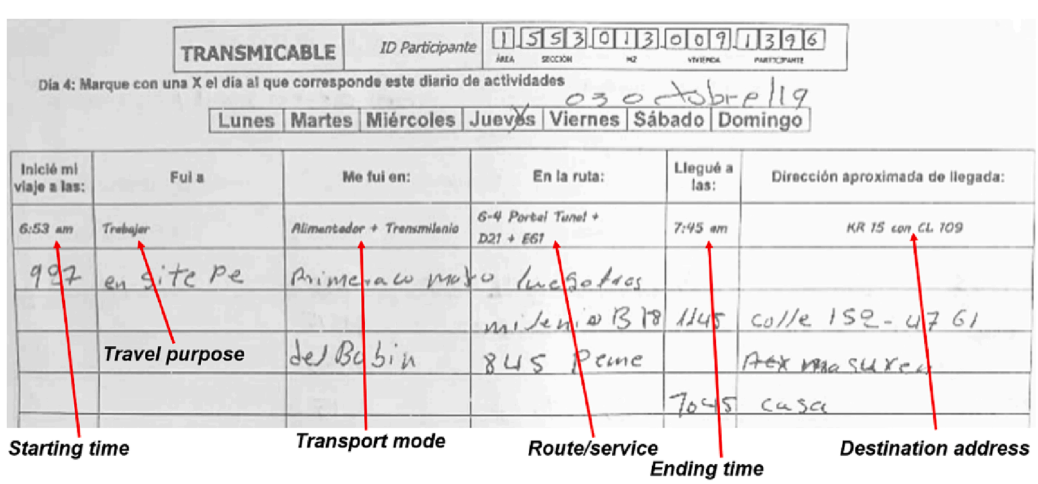

Fig. 3. Travel diaries data collection example.

row represented an activity with its travel diary identifier and each column represented the considered activity category. After data processing, the final sample consists of 220 individuals on T0 and 170 individuals on T1. Only 112 individuals provided valid travel diary information on T0 and T1. Although the sample is not representative of the TransMiCable influence area, this is a unique opportunity to have time-use information before and after the implementation of the project. The authors consider it to be an indicative sample that suggests patterns and behaviors of people residing in the area. An indicative sample is a subset of a population chosen based on convenience or accessibility rather than through a systematic sampling method for accurately reflecting the characteristics of the whole population. Then, indicative samples may not be generalizable to the entire population due to their non-representative nature.

The sample used in this analysis was balanced, which may have limitations for its description but is sufficient for developing econometric models (Tillé, 2011). When discussing a suitable sample for modeling, we emphasize the importance of a sample size that is sufficiently large to provide statistical power and reliability in estimating model parameters. A larger sample size typically yields more dependable estimates and strengthens statistical inference. In this instance, our sample may not be entirely representative of the population; however, the convenient and balanced manner in which it was collected ensures that the relationships modeled in the econometric analysis apply to populations with similar socioeconomic and travel characteristics.

4.3. Descriptive statistics of the sample

Of the total of the sample, 74 % were women and 26 % were men, and the average age was 43.5 years old. Half of the participants were married or living with a partner and 55 % were working or studying. Most participants attained a maximum of primary or secondary level education and reported a monthly household income of two or fewer minimum wage salaries (less than 450 USD/month). Self-reported average travel time for (one-way) commuting trips was 110.0 min. After the inauguration of the project, the average travel time for those trips decreased to 90.2 min.

Table 1 presents the gender and age-group distribution of the final sample. Most participants were women aged between 27 and 59 years old who had at least primary and secondary education and lived in SES 1 and 2, which are the poorest areas of the city. Their household income was less than the minimum wage established in the country. Approximately 90 % of trips made in the area included public transport, and when comparing T0 and T1, we found that around 12 % of the participants reported using TransMiCable regularly, although 76 % have used the cable car.

Participants reported 878 days of activities during the baseline (T0) and 791 days of activities during the follow-up (T1). Table 2 summarizes the frequency and mean duration of daily activities reported in the sample during the two stages.

Disaggregating the previous results, the only activities that increased their average duration were work (4.97 to 7.15 h) and leisure (2.39 to 3.36 h). Leisure time is a key indicator of well-being, because as has been seen in the study area, the greater the possibility of participating in

Table 2
Frequency and mean duration of daily activities.

Activity	Baseline		Follow-up		Mean duration differences†	
	Times chosen	Mean duration [h]	Times chosen	Mean duration [h]	Value	p-value
Drop-Off/pick-up	49	1.35	89	1.12	0.23	0.436
Errands	367	2.41	306	2.00	0.41	0.037**
Exercise	190	2.50	55	1.91	0.59	0.060*
Leisure	208	2.39	129	3.36	−0.97	0.011**
Study	15	3.50	20	2.75	0.75	0.260
Travel	564	2.17	664	2.24	−0.07	0.532
Work	270	4.97	241	7.15	−2.18	0.000***
Stay at home	878	18.81	791	18.28	0.53	0.023**

Significance level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
† Differences between baseline and follow-up for the *Mean duration* variable when the activity is chosen.
Note: Since the variable *Times chosen* is equal to the total number of responses, it is not possible to perform a test of difference of means.

leisure activities, the higher the subjective well-being (Guzman et al., 2023a).

4.4. Modeling framework

The MDCEV model is an econometric model designed to investigate consumer behavior in scenarios where individuals encounter both discrete and continuous options. In such contexts, individuals often confront choices among various alternatives, such as activities throughout the day, and determine their consumption quantities, such as the time allocated to each daily activity. Thus, the MDCEV model facilitates the analysis of time-use decisions. The MDCEV model postulates that individuals face a budget constraint concerning their total time, wherein they select activity participation and distribute their time among different activities to maximize their utility, following the random utility maximization (RUM) framework. The utility associated with each activity is contingent on several factors, including its duration, location, social context, and individual-specific characteristics. The model assumes that individuals possess a utility function for each activity that reflects their preferences over the activity characteristics.

The utility function takes an additive form, with the observed characteristics entering linearly and the unobserved characteristics being modeled as a random variable. The unobserved heterogeneity is assumed to follow an extreme value distribution, enabling a closed-form solution to the model. The model also incorporates correlations between the unobserved random variables, allowing for capturing preference heterogeneity across activities. The above characteristic enables capturing the consumption of a good without affecting others. It also guarantees a marginal decrease (Calastri et al., 2017), which is inversely proportional to the consumption of one among the possible alternatives. Bhat (2008) explains that this effect translates into satiation behavior in

Table 1
Gender and age of the sub-sample of adults completing travel diaries.

Sociodemographic factor	Ranges	T0		T1	
		Frequency	Proportion	Frequency	Proportion
Gender	Male	58	26 %	52	31 %
	Female	162	74 %	118	69 %
Age	18—26	43	20 %	19	11 %
	27—40	54	25 %	43	25 %
	40—59	72	32 %	55	33 %
	≥60	51	23 %	53	31 %

the presence of the selected alternative. The mathematical form of the utility function is presented in Eq. (1), assuming independent observed utility proportion and positive marginal utilities.

$$U(x) = \sum_{k=1}^{K} \frac{\gamma_k}{\alpha_k} \psi_k \left(\left(\frac{x_k}{\gamma_k} + 1 \right)^{\alpha_k} - 1 \right) \quad (1)$$

where ψ_k is the baseline utility of good k, α_k is the inverse parameter of satiation related to good k, and γ_k is the satiation translation parameter associated with good k. *U(x)* is a quasi-concave, increasing, and continuously differentiable function used to calculate the utility of consuming x_k times the good k. The baseline of the utility (ψ_k) is the zero consumption of good k. The inverse parameter of satiation α_k is used to normalize the utility and is exclusively related to the satiation effect. The satiation translation parameter (γ_k) represents the amount of good k consumed. The extended definition of the model is in Bhat (2008).

Finally, the MDCEV model considers a probability P (see Eq. (2) of choosing the consumption vector (x_1*, x_2*, …, x_M*, *0*, …, *0*) of M out of the k alternative goods. The probability of choosing a vector consumption is an i.i.d. extreme value for the stochastic part of the utility (Calastri et al., 2017), where σ is a scale parameter.

$$P(x_1^*, x_2^*, \cdots, x_M^*, 0, \cdots, 0) = \frac{1}{p_1} \bullet \frac{1}{(\sigma^M - 1)} \bullet \left(\prod_{m=1}^{M} f_m \right) \bullet \left(\sum_{m=1}^{M} \frac{p_m}{f_m} \right) \bullet \left(\frac{\prod_{m=1}^{M} e^{V_i/\sigma}}{\sum_{k=1}^{K} e^{V_k/\sigma}} \right) \quad (2)$$

In this paper, we made the following considerations regarding budget, normalization profile, and sociodemographic variables influencing the utility and satiation parameters. A defined budget line constrains the utility. In this case, we defined the budget T as 24 h, representing the sum of the available hours to report activities in the activity diaries. Following Calastri et al. (2017), we considered the weight factors as a unit of time, which is 1 h in this case. The mathematical expression to calculate the budget is shown in Eq. (3), where the base to compare is the *stay-at-home* activity ($k = 1$) (Bhat, 2008).

$$\sum_{1}^{K} t_k = \mathrm{T} \qquad t_k \geq 0 \forall k \in (k = 1, \cdots, K) \quad (3)$$

As defined in Bhat (2008), three normalization profiles consider α and γ parameters. The first method considers a unique α for the alternative defined as an outside good. This is done by fixing α to 0 and estimating the γ_k for the other alternatives. The second method estimates a specific α and fixes $\gamma_k = 1$ for all considered alternatives. The third and selected normalization method defines a generic α parameter. It estimates a specific γ_k for each alternative, following the best efficiency-focused parametrization found in the literature (Pinjari and Bhat, 2010b).

The discrete component of the model includes several sociodemographic variables. The base marginal utility ψ_k of each alternative considers dummy variables representing gender, age, regular usage of the cable car, and changes in the main activity participation. We defined age ranges as 18 to 26 years (youth), 27 to 59 years (adult), and 60 or more for the elderly. Cable car regular users were those who reported frequent use of TransMiCable. Finally, we used a dummy variable taking the value of 1 if the participant changes his/her main activity between stages (T0 and T1) or 0 in other cases. In addition to the discrete component and following Calastri et al. (2017), we also included sociodemographic variables within the continuous components of the model (i.e., the translation parameters γ_k).

5. Results

The MDCEV model was estimated using the Apollo package (Hess and Palma, 2019) by combining T0 and T1 data to compare time use before and after the implementation of TransMiCable, allowing for scale differences between datasets. Particularly, we assumed that the scale parameter for T0 is fixed and takes the value of 1, while we estimated a scale parameter (μ) that multiplies the utility functions in T1. In the data pooling approach, this scale parameter μ, along with the assumption about the scale parameter for T0, would then represent the scale parameter relation between the two periods T0 and T1, which allows equalizing the variance of both data sources. As mentioned in the previous section, the model includes sociodemographic factors in the discrete and continuous components.

It is also important to recall that under the data pooling approach, it is possible to consider generic attributes to both data (T0 and T1 in our case) and other specific ones. For the sake of clarity, to identify specific parameters, we introduced the term "T1" at the end of the parameter description in Tables 3 and 4. In this way, parameters ending in "T1" indicate that they are specific to representing the period after the TransMiCable implementation. On the other hand, those parameters in the results tables that do not include "T1" at the end of their description refer to generic coefficients for both periods, T0 and T1. This section presents the estimation results for the discrete and continuous components of the model.

5.1. Activity participation

Table 3 presents estimates of the discrete component of the model that allows analysis of individual preference for activity participation.

The baseline-specific constants (δ) in Table 3 represent the probability of choosing an alternative compared to the *stay-at-home* activity. The negative sign of several of the δ_k parameters (the first in each category) suggests a higher preference for *stay-at-home* activity. It is important to note that the parameters ending in "T1" enable the evaluation of the project's effect. Combining the T0 and T1 data results in a μ value (scale difference) of 1.01, which is not statistically different from 1. This suggests that separate models could be created for T0 and T1, with comparable coefficient estimation results, given the absence of significant differences between the scale factors.

Table 3
Discrete component estimation results for baseline and follow-up model.

Parameter	Estimate	Rob. t-stat
δ Stay at home	0	Fixed
δ Errands	−1.52	−10.02***
δ Exercise	−1.68	−5.35***
δ Exercise − adult T1	−0.35	−4.38***
δ Exercise − young adult T1	−0.52	−2.53***
δ Exercise − women	−0.06	−1.55
δ Study	−2.44	−3.02***
δ Study − young adult	0.51	5.51***
δ Study − cable car regular users T1	0.50	4.30***
δ Drop-off/ Pick-up	−2.15	−3.37***
δ Drop-off/ Pick-up − adult	0.22	3.60***
δ Drop-off/ Pick-up − young adult T1	0.42	3.34***
δ Drop-off/ Pick-up − women T1	0.17	2.81***
δ Leisure	−1.72	−7.65***
δ Leisure − young adult	0.12	2.89***
δ Work	−1.80	−3.82***
δ Work − adult	0.29	5.95***
δ Work − young adult	0.35	5.45***
δ Work − women	−0.15	−3.61***
δ Work − primary activity change T1	0.14	2.19***
δ Work − cable car regular users T1	0.27	3.50***
δ Travel	−1.38	−5.64***
δ Travel − adult	0.10	3.86***
δ Travel − young adult	0.25	5.78***
δ Travel − cable car regular users T1	0.26	3.467***
Scale parameter (σ)	0.21	25.71***
Scale difference T1/T0 (μ)	1.01	75.04***

Significance level: *** $p < 0.01$ ** $p < 0.05$, * $p < 0.1$.
Note: Parameters ending in "T1" represent the evaluation period after the implementation of TransMiCable.

Table 4
Continuous component estimation results.

Parameter	Estimate	Rob. t-stat
α base	0	Fixed
γ errands	3.31	10.11***
γ exercise	5.25	8.95***
γ study	12.78	6.33***
λ study – women T1	−9.49	−3.74***
γ drop-off/pick-up	1.81	5.05***
γ leisure	5.57	8.11***
γ work	18.29	5.51***
λ work – women	9.49	2.04***
γ travel	2.30	11.68***
λ travel – young adult	−0.64	−2.81***
λ travel – change in primary activity T1	0.55	1.55

Significance level: *** $p < 0.01$ ** $p < 0.05$, * $p < 0.1$.
Note: Parameters ending in "T1" represent the evaluation period after the implementation of TransMiCable.

The model results shed light on the differences in activity participation based on socioeconomic characteristics, such as age and gender. We did not find differences by income level or vehicle ownership. During T0 and T1, women were less interested in exercise (−0.06) and work-related activities (−0.15) than men. This highlights gender inequalities in participation in these activities, consistent with the existing time-use literature (Zhang et al., 2005). The implementation of TransMiCable did not change the duration of activities but did change the probability of participating in certain activities (mainly work, travel, exercise, and drop-off/pick-up). For instance, after the TransMiCable implementation, women were more likely to participate in drop-off/pick-up activities than men (+0.17).

The estimates associated with the age variable also provide interesting insights. While the preference of adults and young adults to engage in exercise activities decreased compared to other age groups after the TransMiCable implementation (−0.35 and −0.52, respectively), the participation of young adults in drop-off/pick-up activities increased compared to other age groups (+0.42). During both periods, young adults exhibited the highest probability of participating in work (+0.35), travel (+0.25), leisure (+0.12), and study activities (+0.51), compared to the rest of the age groups. According to the model estimates, regular users of TransMiCable increased their preference to participate in travel, work, and study activities compared to the rest of the sample. Thus, TransMiCable implementation increased their user preference for traveling.

Furthermore, the results suggest that participants who changed their primary activity are more likely to be engaged in work-related activities after the implementation of TransMiCable (+0.14) compared to those who did not change their primary activity. In summary, TransMiCable is associated with greater participation in work and study activities for the residents. For some individuals, it resulted in a change in their primary activity, while others preferred to use the time saved during travel to stay at home. It is important to note that the effect of TransMiCable on activity participation varied based on factors such as gender, age, and usage frequency. Regular cable car users benefited the most from the implementation of TransMiCable.

5.2. Activity duration

This section examines the continuous component of the model, focusing on the allocation of time to various activities. Specifically, Table 4 presents the estimates of satiation translation parameters (γ_k). These estimates indicate that all activities show increased satiation effects, leading to longer time allocation if respondents choose to participate.

The results in Table 4 suggest that, similar to activity participation, time allocation varies by gender and age. Women allocated less time to study activities (−9.49) than men after implementing TransMiCable (T1). However, their time allocation to work activities remains higher than that of men during both periods (+9.49). Young adults allocated less time to travel compared to other age groups, indicating a greater reluctance to spend their time traveling (−0.64).

Finally, the implementation of TransMiCable increased time allocation for travel among those who changed their primary activity during both periods. This group of individuals likely benefited the most from the adoption of the transport system as it enhanced their accessibility levels, allowing them to conduct activities farther away from home.

6. Discussion and policy recommendations

In urban contexts where willingness to work declines with travel time, unaffordable and low-quality public transport systems pose a significant challenge for millions, particularly within disadvantaged communities. Long travel times, lack of coverage in peripheral areas, and the low level of service offered by some public transport systems constrain the social and economic development opportunities of these populations. Improving the built environment and access to efficient and quality public transport is crucial for the social and economic development of the poorest populations. By reducing travel times, there is greater productivity and time for family and leisure, facilitating accessibility to urban opportunities, and fostering social inclusion.

The TransMiCable project, along with its urban renovation efforts, successfully connected a poor and traditionally neglected area to the city, resulting in numerous positive changes. Not only did the project reduce travel times, but it also had a transformative impact on the lives of the residents. Particularly, the cable car improved accessibility for young adults and adults, as they are more likely to work, study, and engage in drop-off/pick-up activities (errands). However, participation in exercise activities was sacrificed. The project's outcomes are promising, showing how a comprehensive transport project and an understanding of time-use and travel behavior can inform broader transport policies.

Considering that the primary objective of public amenities, in this case, a comprehensive urban intervention, is to provide opportunities for socioeconomic development, healthcare, leisure, and enhancing the well-being of the population (Oviedo and Guzman, 2020), the findings underscore the importance of having available time to engage in activities that contribute to subjective well-being and social welfare. Thanks to this project, the community experienced a reduction in their previously extensive commuting times, increasing the duration of activities related to work and leisure. However, travel times continue to be significant. The relationship between travel time savings and time allocation can significantly influence various policy decisions concerning public transport systems. For instance, policies related to the design and implementation of public transport corridors can incorporate environmental designs and programs that promote leisure, recreation, and physical activities. Additionally, utilizing information on specific personal and social contexts before and after the project's implementation offers valuable insights into the activity and time-use patterns induced by the project. Employing a method that simultaneously estimates the choice of activity types and durations further enhances the evaluation and analysis process.

In segregated cities like Bogotá, integrating aspects such as social support, gender, income, and caregiving within a comprehensive framework allows for a better understanding of individuals' time and spatial patterns, especially within vulnerable communities. Incorporating walkable spaces, parks, and social facilities into transport projects is crucial. By doing so, time savings can be effectively utilized for several activities, such as leisure and recreation. However, it is also important to highlight that not everything should be limited to building more infrastructure. It would be advisable to also include complementary services such as recreational and educational programs that are attractive to residents. For example, our findings are very useful for the policy of care of the city in which the program block of care was implemented in this area, and they offer leisure activities for unpaid caregivers who have time poverty (Guevara-Aladino et al., n.d.). These elements play a significant role in addressing transport-related social exclusion issues.

7. Conclusions

This study examines the activity diaries of hundreds of residents living in a marginalized and historically excluded area on the outskirts of a large Latin American city. The aim is to analyze their activity choices before and after the implementation of a large urban intervention, which includes a cable car system. Our analysis using an MDCEV model reveals that the project implementation mainly influenced the probability of participating in certain activities. We did not observe important changes in the duration of activities. In this case, the only significant change is that women spent less time studying in T1 (−9.49, see Table 4). Additionally, young adults do not want to spend as much time traveling, as they are the group that allotted the least time to travel. Perhaps this population group carries out its activities closely. As seen, changes largely depend on the age group and gender of the person. The gain in accessibility in the area had a positive impact by increasing the probability of working, studying, and errands, but at the cost of less physical activity. Furthermore, given the greater preference for staying at home, this may suggest that reduced travel time allows some individuals to allocate more time to leisure and family pursuits.

The findings of this study offer valuable insights into implementing alternative public transport within economically disadvantaged communities. Firstly, it helps identify current time-use patterns and the factors influencing them. Secondly, time-use research enables the evaluation of the new transport project's impact on time-use patterns. The allocation of saved time to more enjoyable activities rather than traveling represents a noteworthy structural advantage of a public transport project, a phenomenon rarely explored in the literature, particularly in Latin American cities and vulnerable communities. This evaluation can identify the advantages of the proposed project, such as reduced commuting time and improved accessibility to new opportunities and activities. Furthermore, time-use research can inform public policies and urban planning decisions. These insights could be applied in other similar contexts, where governments should prioritize investment in urban renewal with efficient and quality public transport infrastructure, especially in areas where the poorest population resides.

This study has several limitations that require further research to overcome. Firstly, the data relied on information provided by the respondents, which introduces the possibility of memory bias and underreporting of certain activities. To address this issue, we implemented measures to mitigate the effect. For instance, we contacted the respondents every day of the week to remind them to complete the diaries, and during the survey collection, we reviewed the diary with each respondent. Secondly, despite the considerable efforts invested in time and funding to collect the information, we encountered an attrition rate of approximately 48 %. Moreover, the collected information exhibited errors and gaps. Consequently, the sample was not intended to be representative of the population within the influence area of TransMiCable. This limitation restricted our ability to test interactions between certain independent variables, as the resulting groups were insufficient. While we identified changes in activity participation and time allocation due to the TransMiCable project, we are assuming that reallocating time used before mandatory trips brings more enjoyment and satisfaction than travel or previous activities. Leisure time plays a crucial role in people's lives, and recent research supports this notion (Guzman et al., 2023a). However, additional research is necessary to determine how these vulnerable communities value each minute spent on the various activities. Lastly, given the homogeneity of our population in terms of socioeconomic characteristics, it is conceivable that we may overlook variations stemming from unaccounted variables. To enhance future research, we might incorporate a more diverse population or integrate additional control variables.

Luis A. Guzman: Conceptualization, manuscript writing, analysis of results, content planning and review (corresponding author). Julian Arellana: resources, modeling, validation and review. Olga Sarmiento: Literature research and data collection.

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CRediT authorship contribution statement

Luis A. Guzman: Conceptualization, Funding acquisition, Investigation, Supervision, Writing – original draft, Writing – review & editing. **Julian Arellana:** Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Olga L. Sarmiento:** Project administration, Resources, Writing – original draft.

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